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STATE OF TENNESSEE.

STATE GEOLOGICAL SURVEY.

Wilbur A. Nelson, State Geologist.

## BULLETIN 22

# Geology and Natural Resources of Rutherford County, Tennessee

By J. J. GALLOWAY

NASHVILLE, TENNESSEE.
1919

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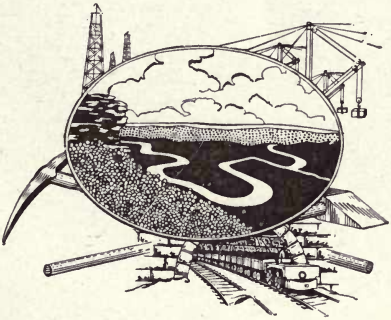

NASHVILLE, TENNESSEE.

1919

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# Geology and Natural Resources of Rutherford County, Tennessee

By J. J. Galloway

## PREFACE

The survey upon which the present report is based was made in the summer of 1915 for the Tennessee Geological Survey and the Department of Agriculture of the University of Tennessee. The survey was conducted by the writer in association with Mr. H. N. Coryell, of Indiana University, to whom he is especially indebted for efficient assistance. The mapping of the areal geology of that part of the county included in the Woodbury quadrangle, an area of 62 square miles, was done by Dr. E. O. Ulrich and Dr. R. S. Bassler, of the U. S. Geological Survey, in the summer of 1908.

The base map for the parts of the county included in the Murfreesboro, Woodbury, Hollow Springs, and Nashville quadrangles was surveyed by the U. S. Geological Survey. The remainder of the county was surveyed, for the base map, by Mr. Fred Maloney and Mr. G. M. Ferris, of Knoxville, Tenn., in the summer of 1915.

Acknowledgment is also due to the late Dr. A. H. Purdue, State Geologist of Tennessee, for his hearty co-operation; to Dr. E. O. Ulrich for his services in the identification of the geologic formations, and to Mr. C. A. Malott for valuable assistance in the interpretation of the physiographic history of the county.

The purposes of the survey were: (1) to determine the natural resources of the county; (2) to gather data for a detailed study of the geology; and (3) to furnish a basis for the study of the soil, in an endeavor to increase its productivity and to reclaim waste land. The soil survey is not yet completed. A report on the paleontology of the Stones River group is being prepared by Mr. H. N. Coryell.

# CHAPTER I.

## INTRODUCTION

### Location and Extent

Rutherford County is the central county of the State. The geographical center of the State is on an area of bare rock of about ten acres in extent, two and one-half miles northeast of Murfreesboro on the Lascassas pike. The county is also near the center of the physiographic region known as the Central Basin.

The county has an area of approximately 607 square miles. It is bounded on the north by Wilson County, on the east by Cannon and Coffee counties, on the south by Bedford and Marshall counties, and on the west by Williamson and Davidson counties. The southern boundary follows approximately the watershed or divide between the Stones River and the Duck River drainage basins, and the western boundary was designed to follow the divide between the Stones River and the Harpeth River basins.

The east, south, and west boundaries, and also part of the north one, are very irregular. Many of the irregularities were made by the State Legislature in response to petitions from farmers who owned land along the line, in order that the "liners" might pay their taxes and vote in the county which was most convenient for them. The county is, however, largely a natural geographic unit.

### Towns

Murfreesboro, the county seat, is the largest town in the county and has a population of about 5,000. It is the most important trading center in the county and is accessible from all directions by good pikes. It is near the center of the county and the center of the best farming country. It has several important industries which add to its prosperity, among them, two pencil factories, a cedar woodenware factory, cotton gins, sawmill, cedar post factory, and a flour mill.

Other important towns are Smyrna, a rapidly growing town in a good farming region, Christiana, Eagleville, Fosterville, and Lavergne. Scattered over the county at distances of from six to twelve miles from Murfreesboro are numerous little villages which support one or two stores.

## Railroad and Roads

One railroad, the Nashville, Chattanooga & St. Louis, traverses the county from northwest to southeast, through the towns of Lavergne, Smyrna, Murfreesboro, Christiana, and Fosterville, and it is one of the principal assets of each of these towns and of the county. Another railroad, the Louisville & Nashville, follows the county line west of Eagleville for about three miles, and furnishes an outlet for produce from that locality.

The county in 1918 had 103 miles of toll pikes and 137 miles of county owned pikes. There are about 400 miles of second-class roads, partly improved dirt roads, which are owned by the county, and about the same amount of third-class or unimproved and private roads. About one-third of the county, the third of which Murfreesboro is the center, is adequately supplied with good roads. The surrounding two-thirds of the county has less than half the mileage of piked roads which it should have in order that farmers may get their products to market as economically as possible.

Good roads are the first requirement for successful farming and the best indication of the prosperity of an agricultural region. In order that Rutherford County may develop its natural resources to their full possibilities it will be necessary, first of all, to build at least 400 miles more of first-class roads, and to repair and keep in repair the pikes it already has.

## Climate

The climate of Rutherford County is on the whole agreeable, but the summers are too warm to be conducive to systematic habits of industry. The first frost comes about the middle of October and the last one in April, so that the growing season is long enough to allow the ripening of cotton. The reddish-brown soil absorbs heat during the day and radiates it at night, so that in July and August both days and nights are warm.

The annual rainfall is about 50 inches. This amount is sufficient, if evenly distributed throughout the year, to supply the needs of all crops. Destructive winds are of rare occurrence. The hills which nearly surround the county protect it from high winds. Gentle winds blow through the valley of Stones River nearly every day.

### Economic Resources

The soil is by far the most valuable natural resource in the county. It works well and is fertile, yet it does not produce one-half of what it should. With proper methods of farming the soil could be made to produce easily twice as much per acre as it now does.

The assessed value of the county outside of Murfreesboro is $6,000,000 (1914), an average of $15 an acre for the 388,500 acres in the county. This estimate includes the town property outside of Murfreesboro and also personal property. Making these deductions it is probable that the assessed value of the land alone would be about $10 an acre for the whole county. The land of the central part of the county is, however, worth three or four times as much per acre as that surrounding it. By the application of scientific farming methods, and good free roads, the assessable valuation could in five years' time be raised to double the present amount.*

Next in importance to the soil as a natural asset comes the rock, with which the county is over supplied. There is an abundance of rock suitable for making roads, for cement, and also for liming the soil to increase its productivity. The benefit to be derived from the use of ground limestone as a corrector of soil acidity is just beginning to be recognized by the farmers.

The forests of red cedar which thrive so well on the glades are being exploited to their full capacity. Many areas which will raise nothing else of value have been robbed of their cedars, and the attempt should be made to reforest these glades and other waste land. A large income could be derived from the growing cedar forests at a small outlay of time and money.

The potential water power of Rutherford County is much greater than that now being utilized by the small grist mills along the branches of Stones River. The narrow gorge through which the river runs furnishes favorable conditions for the building of dams and unfavorable for the storage of water, viz.: (1) short dams, therefore low initial expense, and (2) the backwater would not spread out over much farmable land. The narrow gorge has the disadvantage, however, of requiring high dams in order to hold enough water to last during dry season. The potential water power of the country is unknown. Very little of this power is now being developed. The power could be made to generate electricity, as is now being done at Walter Hill.

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*Mr. A. V. Louthan, Chief Tax Statistician of the State Board of Equalization, states that in 1918 the total assessment of all realty was $6,892,434, while in 1920, the total valuation will be $26,070,985. On personal property the valuation in 1918 was $1,266,675, while in 1920 it will be approximately $5,000,000.

The natural and other resources will be discussed in detail in a separate chapter.

# CHAPTER II.

# TOPOGRAPHIC DESCRIPTION

## THE RIM OF HILLS

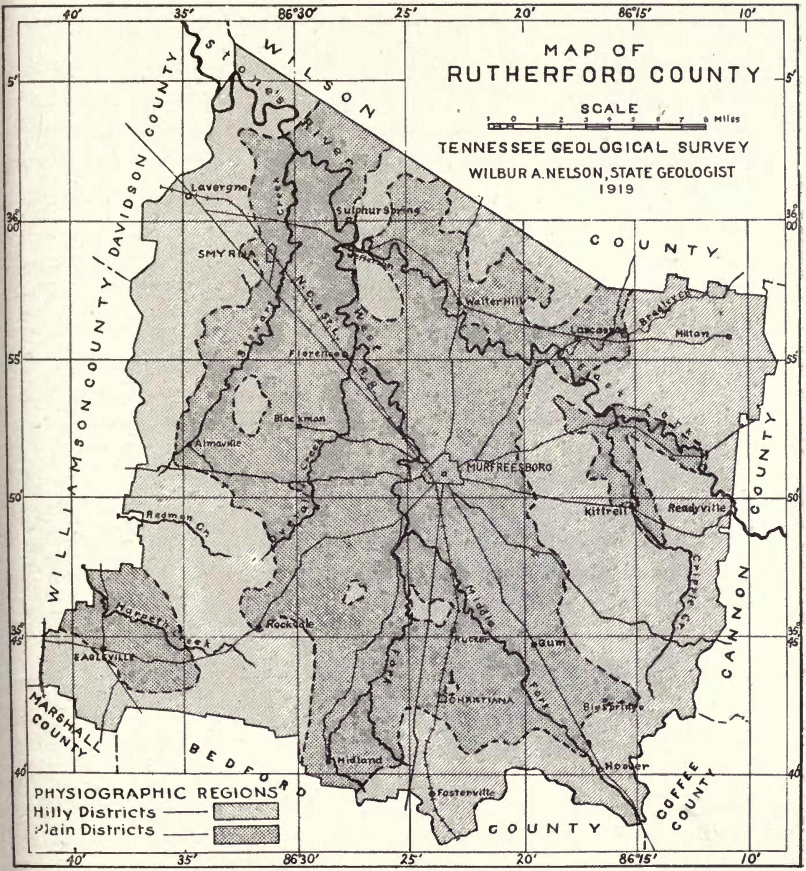
The county is nearly surrounded by hills, which are the remnants of the Highland Rim. The county includes very little of the Highland Rim proper, but it has many hills which are as high as the Rim, and several ridges, especially in the southeastern corner of the county, which are remnants of the Rim. The largest remnant is a ridge three or four miles long with several branches, about three miles east of Big Springs. The top of this ridge is the highest elevation in the county, 1,352 feet, and it is also the highest point in the State west of the Cumberland Plateau, excepting Short Mountain in Cannon County.

The tops of most of the hills and ridges along which the county line runs between Cannon, Coffee, and Bedford counties, and Rutherford from the Bradyville pike south and west to the Shelbyville pike, are at an elevation of about 1,300 feet. The belt of hills between the Bradyville and Manchester pikes is about four miles wide. The valleys are narrow and V-shaped and the hills are steep, having a rise of about 500 feet in the last mile to their tops. A lower belt of hills along the county line from the Manchester pike to the Shelbyville pike is much narrower, being from one to two miles wide. They are quite steep, rising from 300 to 500 feet in a mile at places.

The tributaries of Stones River have cut back into the Highland Rim, making many narrow hollows, and at Hoovers Gap the river has cut nearly through the divide between Bedford and Rutherford counties. This divide, as well as all the other hills in the county, is merely a remnant of the highland which once extended over the entire Central Basin.

From the Shelbyville pike around to the Franklin road the county line runs over fairly level country. The former highland in the southwest corner of the county has been reduced to isolated hills.

PLATE 1



Map of Rutherford County, showing Physiographic Regions.

Between Williamson and Rutherford counties, north of the Franklin road, is a range of high hills, the highest ones of which reach an elevation comparable to the highest ones in the southeastern corner of the county, that is, about 1,300 feet. Signal Hill and Sumners Knob are capped with the same formation as that found on the hills bordering the Plateau of the Barrens, the Ft. Payne chert. The top of Sumners Knob is about 550 feet above the more level country to the east.

There are no high hills between Davidson and Rutherford counties, nor in the northern corner, but there are numerous small, round hills. The eastern side of the county includes several ranges of high hills which are prolongations of the Highland Rim. Many of the hills on the border adjoining Wilson County, north of Lascassas, have a bench or terrace near the top. These hills are capped with solid limestone (Cannon), below which is a sandy limestone (Hermitage), which weathers readily and produces a fertile, tillable soil. Below the sandy rock is another solid bed of limestone (Carters), which is resistant to weathering. The sandy rock weathers faster than the limestones above and below, and makes the more or less level zone or terrace around the hill.

The eastern third of the county is quite rough, the hills for the most part being in long ridges with a northwesterly direction. The valleys between the ridges are wide and fairly level. The hills in the eastern third of the county occupy something like 70 per cent of this area.

## THE CENTRAL PLAIN

The central and western parts of the county, about one-half the total area, may be classed as level or rolling. These parts, here called the Central Plain, have an elevation of about 500 feet in the northern corner and 700 feet in the southern and western ends of the county. The larger portion of the plain has an average elevation of 600 feet. The lowest point (475 feet) is where Stones River leaves the county.

The level part of the county is essentially a peneplain (nearly a plain). It had been reduced in the Pleistocene or Glacial period, as low as running water would make it. Scattered about over the Central Plain are isolated hills or small ridges (monadnocks). Conspicuous examples of these are the Marshall Knobs, north of Rucker, Barfield Knobs, Pinnacle Knob, Blackman Hills, and the knobs just west of Eagleville.

## DRAINAGE

The county is drained almost wholly by Stones River and its tributaries. About 60 square miles, north and east of Eagleville, are drained by the headwaters of Harpeth River. The water which falls south of the hills south of Eagleville, an area of about 8 square miles, drains out through one of the tributaries of Duck River.

## GLADES

*Definition.*—The more or less flat areas of bare rock, or rocky places which are valuable only for pasture or raising timber, are known in Tennessee as "glades." The word "glade" originally meant "an open space in a wood"; next the word was applied to the cause of the open space, in this case rock, and now it is applied to any rocky place whether the trees still surround it or have been removed.

### KIND OF GLADES

There are two main kinds of glades in Rutherford County: (1) the typical red cedar glade, which is a flat or hilly region of platy, thin-bedded limestone (Lebanon or rarely Pierce), where only red cedars and prickly pears will grow; (2) the massive-rock glades, or hardwood glades, on which grow, or have grown, oak, hickory, and locust, but only a few cedars.

The cedar glades (from which the Lebanon or "Glade" limestone takes its name) occupy a large proportion of the area of the county, probably 160 square miles, or over one-fourth of the total area. The eastern hilly third of the county is characterized by the cedar glades. They form an irregular band from two to ten miles wide nearly surrounding the county. These glades, which are often pastured, grow large quantities of red cedar trees. These are the lowest priced lands in the county. They are valued at from $1 to $10 an acre, depending upon the amount and quality of timber remaining upon them. Sometimes there are a few acres which can be tilled, but the soil is so shallow and poor that a crop cannot stand even a short drought.

The hardwood or massive-rock glades may be considered for convenience to consist of two types: (a) flat areas of solid, bare rock with few cracks, on which nothing can grow, and (b) areas of massive or chunk rock with numerous joints or vertical cracks partially filled with soil. A good example of the first kind is the "center of the State," 2½ miles northeast of Murfreesboro. Abundant examples of the second kind of massive-rock glades may be seen within a mile or two of Murfreesboro, in any direction. Hardly a square mile of the Central Plain is without a patch of this kind of glade.

The rock of the hardwood glades is usually Ridley limestone, but may be Murfreesboro limestone, Carters limestone, or more rarely Cannon limestone. All of these limestones are much alike in their physical and chemical characters, and under similar circumstances produce similar glades.

Grasses and various kinds of trees, mainly white oak, grow in the joints between the flat blocks of limestone. There are all gradations between the proportions of rock and soil of the hardwood glades: (1) the perfectly bare rock without joints; (2) areas where there is only room enough between blocks for trees to grow (numerous examples along the Franklin road); (3) areas of about equal proportions of rock and soil; (4) glades where the soil occupies four or five times as much surface as the rock does; and (5) areas which can be farmed but where numerous knobs or masses of rock are exposed over the field.

## ORIGIN OF GLADES

Glades originate by superficial solution and erosion. The process operates somewhat differently on different kinds of rock.

The Lebanon and Pierce formations are made up of layers of thin, broken slabs of dense limestone, separated by thin films of shale. These limestones weather rapidly by freezing and thawing and by solution of rainwater and groundwater charged with carbon dioxide. Weathering is mainly at and near the surface, and the soluble part of the rock is dissolved and carried away. The small amount of insoluble material, mainly clay, is so fine and impalpable that it is floated away by each rain, or by the heavier rains, as fast as it is produced. The broken slabs shed water like shingles, so that the only soil left is in the numerous joints and cracks. The repeated freezing and thawing and the rains during the winter are sufficient to keep the rock practically free from soil where there is slope enough to allow the water to run off.

When the glades have become so nearly level that most of the rainwater runs into the rock and the remainder flows off very slowly, then the residual clay accumulates and forms soil. After the soil accumulates to a depth of five or six inches, freezing and thawing become inoperative in breaking and loosening the rock, and weathering is then wholly by solution and at a much slower rate. The soil over the Lebanon limestone is never deep, the average depth is probably less than a foot, although sometimes it may be as deep as three or four feet, due to an accumulation of wash from higher places.

Massive rock, with a fine grained dense texture like the Murfreesboro and Ridley limestones, weathers by surface solution. While the rock is massive, it is jointed or fractured every few feet. Rainwater falling on the rock dissolves a little of it, and finally produces a fluted appearance and miniature river systems. It then runs down the joints, carrying the small amount of insoluble clay with it. Solution is also vertical, along the sides of the joints. The joints gradually widen and fill with soil, so that a glade of massive rock would eventually be weathered away and replaced by soil. This is what has happened over the greater part of the Central Plain, and the process of weathering and filling of the joints is responsible for the good, red soil found there.

The small amount of residual material, mainly clay, is, however, often carried away by heavy rains down to the streams and is lost. Again, the clay is frequently carried down the joints to some underground channel and thence to some surface stream. The fact that soil is being removed by underground streams is attested by the muddy or murky condition of many springs and some wells during wet weather. The rainwater which falls on most of the massive rock glades immediately runs into sink holes, carrying the minute amount of rock dissolved as well as the insoluble clay with it. The sink-holes communicate with underground waterways which open along streams or at a lower level.

The massive limestone when dissolved leaves a residue of perhaps five per cent, so that the solution of 20 feet of rock ought to produce one foot of soil, and the 600 feet of limestone removed from the Central Basin ought to leave 30 feet of soil, provided none of it is removed. The soil is, however, on an average less than four feet in depth over this region, so that about 90 per cent of it has been removed. Most of the loss has been by running water, but a small amount of soil has been carried away by the wind.

When a sample of the Ridley limestone is dissolved in acid there is a thick scum of a mixture of clay and oily matter left which floats on the top of the solution. When some of the scum is heated and all the oily matter driven off, there is left a film of white clay. This experiment shows that this oily matter causes some of the residual clay to be buoyed up and therefore carried off by rainwater nearly as fast as it is produced. In this section porous limestones and those containing bituminous matter rarely form glades.

# CHAPTER III.

# TOPOGRAPHIC HISTORY

## STAGES IN THE TOPOGRAPHIC HISTORY

In tracing the development of the present physiographic features and topography of the county, four stages: the hilly rim, the central plain, isolated hills, and drainage may be recognized from features present in Rutherford County, viz.:

1. The Highland Rim peneplain stage (end of the Eocene)
2. High Terrace Gravel stage (end of the Pliocene?)
3. The Central Basin peneplain stage (middle Pleistocene)
4. The Recent Uplift (late Pleistocene and recent)

### THE HIGHLAND RIM PENEPLAIN STAGE

The elevated plain or plateau which constitutes the Highland Rim of Middle Tennessee is the remnant of the plain which once extended entirely across the Central Basin. During the Cretaceous and Eocene periods the agents of weathering and erosion had worn down the surface rocks of Middle Tennessee to a featureless plain which extended from about the present location of the Tennessee River to a line running through Franklin, Warren, and Overton counties, that is, to the foot of the Cumberland Plateau. During that time the Gulf of Mexico extended up the Mississippi Valley as far north as southern Illinois, covering all of western Tennessee to within ten miles of the Tennessee River. The sediments, mud and sand, resulting from the disintegration and decay of 700 or 800 feet of sandstones, shales, and limestones, were carried by the rivers to the extended Gulf and there deposited.

At the end of the Eocene the Highland Rim peneplain varied from sea level, about where the Mississippi River now is, to 400 or 500 feet above sea level along the western front of the Cumberland Plateau. The Highland Rim peneplain was from 1,000 to 1,200 feet lower in Rutherford County than it is now. This ancient plain is not preserved in this county except on the tops of the highest hills bordering the county. It may be seen at the top of the high hills east and southeast of Milton (elevation 1,250 to 1,300 feet), the top of the Ready-

PLATE II

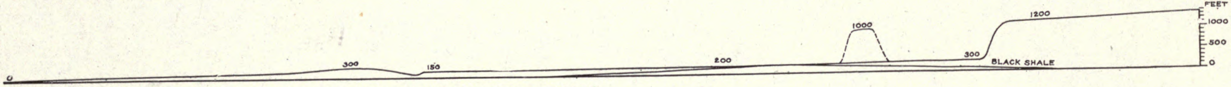


FIG. 1 THE HIGHLAND RIM PENEPLAIN AT THE END OF THE EOCENE PERIOD

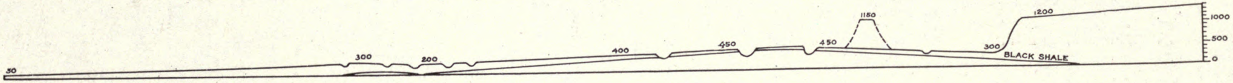


FIG. 2 TOPOGRAPHY IN MIOCENE TIME

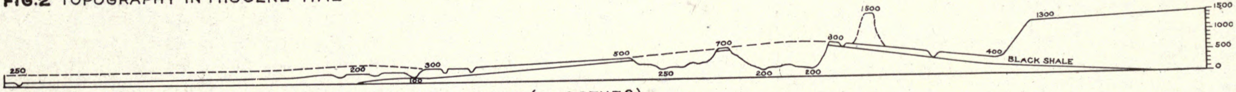


FIG. 3 TOPOGRAPHY AT THE HIGH TERRACE GRAVEL STAGE (PLIOCENE?)

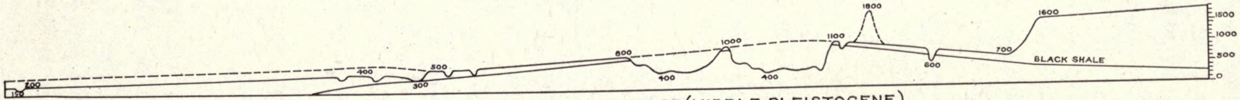


FIG. 4 TOPOGRAPHY AT THE END OF THE CENTRAL BASIN PENEPLAIN STAGE (MIDDLE PLEISTOCENE)

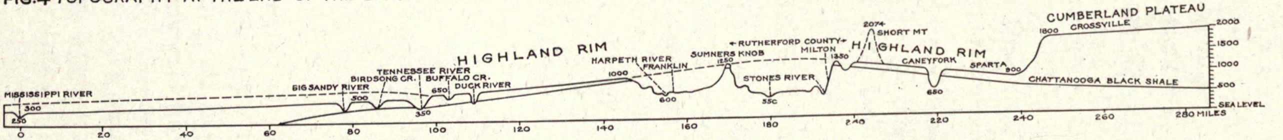


FIG. 5 TOPOGRAPHY AT THE PRESENT TIME

Diagrams showing the topographic history of the Central Basin. Profiles drawn from the Mississippi River to Cumberland county, through the northern part of Rutherford county, latitude 35° 55′. The dashed line is the reconstructed Highland Rim Peneplain. Scale : Horizontal, 1 inch=20 miles; vertical, 1 inch=2,000 feet.

ville Pilot Knob (1,228 feet), Murray Hill (1,276 feet) and the tops of the highest hills on and near the county line from the Bradyville pike to the Shelbyville pike. The highest ridges in this locality are flat-topped and have an elevation of 1,350 feet. These are the highest places to be found in Middle Tennessee on what remains of the Highland Rim peneplain. The Plateau of the Barrens, as well as the flat-topped hills bordering it, are the remnants of this peneplain.

It is not probable that any hills in the western side of the county preserve this peneplain, since none of them are flat-topped, but several of them are nearly high enough and represent approximately the location of the peneplain. Pinnacle Knob, the Eagleville hills, Sumners Knob, and Signal Hill, all have an elevation of about 1,200 feet, which is not far from the present elevation of the peneplain elsewhere in the county.

Fig. 1, plate II, is an ideal cross-section of the Highland Rim peneplain at the end of the Eocene period. Rutherford County at that time had an elevation of 200 or 300 feet above sea level, and the surface rocks and physical features were the same as those now seen on the Plateau of the Barrens.

There had been some folding of the strata in the center of the State before the Eocene period, in the Paleozoic era, and especially at the end of that era, when the Appalachian Mountains were folded up. During the Mesozoic era there was some oscillation, which reached its maximum in the Cretaceous period. The Cretaceous peneplain extended from the top of the Cumberland Plateau (possibly 1,200 to 1,400 feet above sea level after the Cretaceous uplift) to the Tennessee River (then about sea level). There are no remnants of the Cretaceous peneplain in Rutherford County and no deposits which can be assigned to this period.

The rivers had cut down some distance into the rocks below the Cumberland Plateau peneplain during the late Cretaceous while middle and eastern Tennessee were being elevated, but it is highly improbable that they had cut down as far as the Highland Rim. When the rocks were reduced to the latter peneplain during the Eocene any Cretaceous stream gravels were also removed. The thickness of rock removed during the late Cretaceous and Eocene periods varied from nothing in the vicinity of the Tennessee River to 900 feet along the foot of the Cumberland Plateau. The most rapid elevation took place at the end of the Cretaceous, and therefore the greatest erosion took place during the

Eocene. This is also shown by the greater thickness of Eocene deposits in western Tennessee.

During the long Cretaceous and Eocene periods there had been sufficient time for the agents of erosion to cut down through the resistant cherty limestone and sandstone of the Ft. Payne formation to the underlying less resistant Chattanooga ("black") Shale, and possibly even down into the Trenton limestone beneath it, at the center of the dome in Rutherford, Wilson, and Marshall counties. There were some high, isolated hills still remaining on the Highland Rim peneplain at the end of the Eocene period, an example of which is Short Mountain, in Cannon County. This mountain is a remnant of the Cumberland Plateau.

At the beginning of the Eocene most of western Tennessee was below sea level, as shown by the deposits. During the Eocene the Cumberland River and its tributaries no doubt had approximately the same courses they now have, but they meandered about over the featureless plain.

## HIGH TERRACE GRAVEL STAGE

At the close of the Eocene period there was a gradual elevation of Middle and West Tennessee, but the rate and amount of rise was not everywhere the same. The rate of rise was greatest along the axis of the present Central Basin, but was slow enough to allow the Cumberland, Duck, and Elk rivers to maintain their courses across the fold. The elevation continued without interruption during the Oligocene and Miocene periods and into the Pliocene, toward the end of which period the elevation ceased for a considerable time, and there may have been a depression of about 50 feet.

There are no recognizable deposits of either Oligocene or Miocene age in Rutherford County, nor have any deposits of these ages been recognized anywhere in Tennessee. This may be interpreted to mean that all the streams in the State were actively eroding during these periods, and the resulting sediment was carried down into the lower Mississippi Valley and there deposited in the extended Gulf of Mexico. The Gulf then covered the southern portion of the states of Alabama and Mississippi, and deposits of Oligocene and Miocene age have been recognized there.

Fig. 2, plate II, is a diagram of the possible topography of Middle and West Tennessee during the Miocene period. It is not a definite stage, but is merely intermediate between the Eocene and the Pliocene stage. It is introduced to show the differential rise of the Central Basin region.

Toward the end of the Pliocene period the rivers of the Central Basin region had cut down to about 200 feet above sea level, which was as low as they could cut. Then then began to meander. The headwaters of Stones River had a high gradient, as they now have, and they carried sand and gravel from near the tops of the hills down stream some distance and dropped them, because the water had insufficient velocity to transport them further. These gravels accumulated to a depth of 50 or 60 feet in the valley of the east fork of Stones River, and no doubt had a similar thickness at other places in the county. The hills surrounding the county were then 700 to 800 feet above sea level.

The hill or terrace gravel is made up of rounded, waterworn pebbles of chert and quartzite, from the size of a marble up to three or four inches in diameter. There is also considerable sand and fine gravel. The mass is not consolidated, but is sometimes slightly cemented with yellow iron oxide. This gravel occupies an intermediate position between the Highland Rim peneplain and the present topography. Similar deposits occur at corresponding elevations along the Cumberland River. These gravels are probably of Pliocene age.

The high gravels may be seen in Rutherford County on a hill five miles northeast of Lavergne (elevation of the top about 580 feet); on a hill two miles southeast of Walter Hill (elevation of top, 700 feet); and on the tops of several hills along the river south of Lascassas (elevation 680 to 700 feet). There are no gravels on the hills in the valley of the west fork of Stones River.

Most of the pebbles of chert in these gravels were derived from the heavy beds of chert at the base of the Ft. Payne formation, which is just above the "black" shale, on the brows of the hills of the Highland Rim. It seems quite probable that the quartz and quartzite boulders, which make up a large part of the terrace gravels, were derived from the lower Pennsylvanian (Lee) conglomerate which caps the western edge of the Cumberland Plateau. The Lee conglomerate was weathered and eroded down into gravel and sand, over the area of the Central Basin and westward, during the Cretaceous peneplanation period, which lasted from the Permian to the early Cretaceous. Since that time the gravels have been worked over by water many times and most of them have been ground into sand and carried down the rivers. The chert and quartzite gravels are so resistant to erosion and decay that some of them remain in the old river channels and even in the present river beds. These hard gravels were also the tools by which the streams were able to sink their beds into the hard Trenton and Stones River limestones.

Fig. 3, plate II, is a diagram showing the topography of Middle Tennessee at the end of the Pliocene. It also shows the possible history of West Tennessee, where there had been considerable erosion since the Cretaceous and Eocene deposits were laid down. The Highland Rim peneplain was probably cut down some 200 feet on the west of the Tennessee River during the Pliocene, and the terrace gravel, derived from the Mississippian and Pennsylvanian rocks to the eastward, was laid down by meandering streams over the newer peneplain.

The Nashville structure dome, the Central Basin region, is shown in Fig. 3 to have risen between 500 and 600 feet since the end of the Eocene, because the high gravels are about 600 feet lower than the Highland Rim, which could not have been much over 200 feet above sea level at the end of the Eocene period. The Cumberland Plateau is supposed to have risen 200 feet and West Tennessee 150 feet during the same time.

## THE CENTRAL BASIN PENEPLAIN STAGE (MIDDLE PLEISTOCENE)

At the end of the Pliocene the rising of the land was resumed, and continued till about the middle of the Pleistocene period, when there was another pause. During this time the Nashville Dome was elevated about 300 feet and the western end of the State some 200 feet. The streams of the Central Basin cut down to an average elevation of 400 feet, which was about base level at that distance by water from the sea. The Gulf embayment had retreated from its former position as far north as Tennessee to somewhere near its present location. The streams then cut down the divides between valleys and reduced the basin of Stones River to a peneplain. Most of the Central Basin reached its present dimensions and topography at that time. The east fork of Stones River cut down about 100 feet below the top of the high gravels.

It is a remarkable fact that there are very few alluvial deposits of Pleistocene age in the Stones River basin. There is no Pleistocene alluvium along the streams, excepting perhaps on the inside of the bends, where some sand and silt has been left as the stream widened its meander and cut down at the same time. What alluvium there is in Rutherford County is most probably recent.

Along the headwaters of the streams of the county where the streams change from a high to a low gradient, there are deposits of gravel, mainly chert pebbles, brought down from the erosion of the rocks underlying the Highland Rim. The best example in the county of an accumulation of gravel of this kind is at the head of Big Creek, about two miles east of Big Springs. Here the gravel is from 2 to 10 feet thick, and made up of rounded and angular pieces of chert and limestone debris. The fact that the streams have recently cut through the gravel is the only evidence I know of which would argue in favor of Pleistocene age for the headwater gravels.

Fig. 4, plate II, shows the topography at the end of the peneplanation period which ended in middle Pleistocene. It was very similar to what it now is, but the Basin was about 150 feet lower.

## THE RECENT UPLIFT (LATE PLEISTOCENE AND RECENT)

About the middle of the Pleistocene or Glacial period the upfolding or doming of the strata in the center of the State was resumed. There has been a rise of about 200 feet since the last stage, for the Terrace gravel is now 700 feet above sea level, whereas in the middle Pleistocene it was about 500 feet. All the rivers of the Central Basin have entrenched their meanders and have removed any sand or gravel which was in the beds or valleys during the Pleistocene, for all the streams now run on clean bed rock and are still rapidly cutting down. The Cumberland River has entrenched itself in its old bed at least 100 feet, as shown in the vicinity of Nashville, where it is over 100 feet lower than the Central Basin peneplain, which has a general elevation of about 500 feet in that locality.

Stones River has cut down to a maximum depth of 60 feet in Rutherford County, where the river leaves the county. There are numerous small falls along both forks of Stones River, showing that the river is still rapidly cutting down and the falls are working back toward the heads of the river. The west fork of Stones River has entrenched about 40 feet at Jefferson, about 20 feet at Murfreesboro, and less and less as one goes up the river, until the recent down-cutting is not noticeable ten miles south of Murfreesboro. The east fork has also entrenched itself to varying depths, depending on the distance from the Cumberland. The amount of down-cutting below the Pleistocene or Central Basin peneplain is about 40 feet at Jefferson, Walter Hill and Bettys Ford, 30 feet at Lascassas, 20 feet at Halls Hill, and lesser amounts farther up the river. The entrenching of the smaller streams is less than it is in Stones River and fades out a few miles from the river.

There is very little alluvium along any of the streams excepting along the inside of the bends, where it was deposited during high water. The beds of all the streams of the county have been swept clean of debris except in a few places where there is limestone debris and chert derived from the limestone, or in some cases, from the Ft. Payne formation.

The topographic history of the entire Central Basin is the same as that outlined above for Rutherford County. The periods of elevation and periods of rest were the same, but the amount of rise and amount of erosion varied at different places. The doming was less in amount both to the north and to the south of Rutherford County and the elevations of the various peneplains and river levels were not the same everywhere in the Central Basin, but the stages in the history and the results attained are strictly analogous to those for Rutherford County.

Fig. 5, plate II, is a diagrammatic profile across western and middle Tennessee showing the topography at the present time. The dotted line is the reconstructed Highland Rim peneplain. The profile is drawn as accurately as the data available and the scale will allow.

The reason for the excavation of the Central Basin in the top of a dome is that the streams cut through the hard, insoluble chert of the Ft. Payne formation during the Eocene period at the place where the strata were already slightly domed, and when further rise took place the streams immediately began cutting into the dense but soluble limestones below. The streams were also shod with chert debris which is much harder than the limestone, so that both abrasion and solution acted on the limestones, but weathering and erosion took place less rapidly in the silicious rocks of the Ft. Payne formation of the Highland Rim.

## THE SHAPE OF THE CENTRAL BASIN

Many people have observed that the Central Basin is similar to a lake basin, and some people have the erroneous idea that it is actually "the bed of a drained lake."* There is no reason for thinking that the Central Basin was ever a lake except its basin shape. On the contrary there are many reasons why it never could have been a lake: (1) there is no evidence that all four rivers, the Cumberland, Harpeth, Duck, and Elk, which drain the basin, or even any one of them, has ever been dammed so as to cover the Central Basin or any part of it with water; (2) there are no beach terraces around the basin, which are a conspicuous feature of most extinct lakes; (3) there are no delta deposits in the basin where the streams which fed the supposed lake would have emptied; (4) there are no lake deposits, such as marl, muck, or black soil, which are always left behind when a lake is drained; (5) there are no deposits with remains of freshwater shells, fish, or other animals which abound in lakes; (6) there are no remains of lake or marsh plants; (7) there is no lake in the world occupying a similar position in an erosion basin on the top of a structural dome, and (8) the basin was formed by erosion and the rocks which once filled it have been eroded and carried away in solution by the rivers, so the rivers were there before the basin.

## CAVES, SINK-HOLES, AND UNDERGROUND DRAINAGE

The rocks under the Highland Rim and out of which the Central Basin was carved, consist almost entirely of dense, brittle limestone. The rocks are broken every few feet or traversed by two sets of joints which run parallel and at right angles to the longer axis of the dome. These joints are largely responsible for the formation of the basin, for they allow the rocks to be weathered vertically a considerable distance below the surface as well as at the surface. After each successive rise, rainwater would seek lower levels through the joints and cracks in the rock, as well as over the surface and down the valleys.

Rainwater dissolves away the limestone fastest where joints cross, and when a hole of considerable size has been formed by solution it is called a sink-hole or sink. Sinks develop in the shape of a funnel, because solution is most rapid near the surface. The funnels collect more water and cause more rapid solution at the bottom of the funnel and along the joints and bedding planes where the water escapes. In this way underground channels are made which sometimes carry considerable volumes of water, and when large enough, are called caves. The underground channels always emerge along some stream and they are called springs, but the water which flows from them is largely surface water and likely to be contaminated. These springs are much like the opening of a tile drain, into the upper end of which a surface stream runs.

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*Safford, Geol. Tenn., 1869, pp. 100-103; Safford and Killebrew, Elem. Geol. Tenn., 1900, p. 23.

Since the Central Basin peneplain was formed and after the recent uplift, thousands of sink-holes have been developed over the central plain of Rutherford County, and much of the water which falls as rain is carried down to the rivers and larger streams through these underground channels. The sinks are not ordinarily over 20 feet deep and most of them have a small diameter, since the time during which they have been forming is comparatively short. Some of the larger ones were probably developed during the Pleistocene. Among these may be mentioned a 60-foot sink and cave one mile northwest of Kittrell, which is 100 feet above Cripple Creek and has an elevation of about 700 feet.

Another of the older sink-holes is the one into which the creek from Fox Camp Spring runs. This sink was developed in the bottom of a small valley where the water found a channel along the cracks in the rock. After running a mile and a half underground this stream emerges at Sand Spring. The water which flows from Sand Spring does not all come from Fox Camp Spring, but the drainage from several other underground streams and sinks empties into the main stream before it emerges. Part of the Sand Spring water is without sediment as it comes through the body of the rock and is therefore filtered, but most of it comes directly from the creek leading from Fox Camp Spring and is surface water, as shown by the fact that whenever it rains Sand Spring becomes muddy.

The water flowing from Fox Camp Spring is gathered from the numerous sinks in the neighborhood of Dillton. The underground channels leading from the sinks are small and the water from them seeps through the cracks of the rock rather than runs. Active solution of the limestone is going on and underground channels are being dissolved and eroded out. The water from this spring has a milky or blue color.

A more obvious example of subterranean drainage is a stream one mile northeast of Florence, near Miles Ford, where the water may be seen running past the bottom of several sinks and under the road and finally emptying into the river. In rainy weather this stream is quite muddy.

One-half mile due east of Marshall Knobs and on the river bank a spring spurts up from a crack in the rock. The water is warm in the summer time and probably comes from a sink one-third of a mile farther east.

The water from Double Springs, three miles east of Murfreesboro, runs into a sink, later appearing in several steep-sided sinks south of Shiloh School. After running straight north it reappears as a spring at the head of Bushnell Creek.

Six miles west of Murfreesboro, near Kings Hill, a large spring empties into Overall Creek. The water which comes from this spring is gathered from numerous sink holes south of Kings Hill. After running down Overall Creek three-quarters of a mile the water, during dry weather, all disappears down a crack in the rocks. It appears again about a mile farther down stream. During wet weather the small underground channel cannot carry all the water, and then it runs down the bed of the creek. This is an excellent example to show the first stage in the development of sinks and underground streams. In a few hundred years the underground channel will be large enough to carry the water at all times, as the one between Sand Spring and Fox Camp Spring does now.

These examples are only a few of the hundreds which may be seen in Rutherford County. The underground drainage and encised meanders show two things of great interest. First, that the land has been recently elevated, and second, the method by which most of the rocks of the Central Basin have been removed, that is, by solution both at the surface and underground. The joints and cracks were produced by the warping of the rock during the rise of the Nashville Dome, which took place for the most part during the Permian, Cretaceous and Tertiary periods.

# CHAPTER IV.

# DESCRIPTIVE GEOLOGY

## HISTORICAL REVIEW

Rutherford County is the type locality of the Stones River group, which was named by Dr. J. M. Safford in 1851 (Am. Jour. Sci. & Arts, 2nd ser., vol. xii, p. 352). The name was taken from Stones River, along which the best and most complete section of the Stones River group may be seen. In 1869 Safford published descriptions of the formations occurring in Rutherford County (Geol. Tenn., p. 258), but abandoned the name "Stones River," thinking that the group was strictly equivalent to the Trenton group of New York, and changed the name to "Trenton, or Lebanon." Winchell and Ulrich recognized the true age and position of the Stones River group (Geol. Minn., vol. iii, pt. ii, p. xc, 1897) and resurrected the name but placed the Carters in the Black River. The descriptions and figures of many species of Stones River fossils from the type locality are published in the Minnesota report mentioned.

Safford and Killebrew, in 1900, published a resume of the geology of the State (Elem. Geol. Tenn., p. 125), in which they included brief descriptions of the rocks found in Rutherford County, and they redefined the name Stones River in the sense in which it now is used. Hayes and Ulrich described the rocks of the Columbia quadrangle (U. S. G. S., folio 95, 1903), which are very much like those of Rutherford County, but the strata of the two areas differ in detail. They also give the range of a considerable number of fossils which are valuable for the identification and correlation of the strata. They also list some of the fossils of the Murfreesboro and Pierce limestones, strata which outcrop only in Rutherford County. In this publication the Carters limestone was again placed in the Stones River group.

## STRATIGRAPHY AND AREAL DISTRIBUTION

The sedimentary or stratified rocks of the earth's crust are divided and subdivided into units according to the age in which they were formed and to their position one above another.

## *ROCKS NOT EXPOSED AT THE SURFACE*

The knowledge of the rocks underlying a region and not outcropping anywhere in that region is obtained in two ways, (1) directly, from the records of deep wells, and (2) indirectly, or by inference from the rocks outcropping in adjacent regions. Several deep wells have been drilled in Rutherford County, but unfortunately the records, if any were kept, of the rocks passed through in drilling the wells are not available for study.

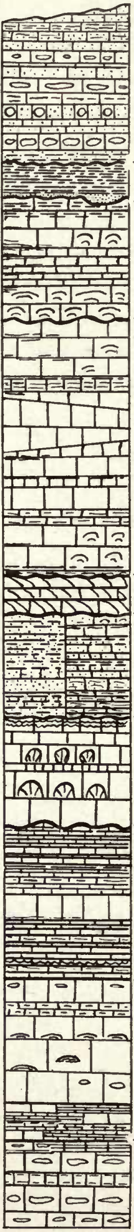
Beneath the Stones River rocks of the Sequatchie Valley and of the Valley of East Tennessee occur several thousand feet of dolomite, limestone, shale and sandstone, the Knox group. In the Wells Creek basin the Stones River rocks are missing and the Lowville, corresponding to the Carters, lies unconformably on the Wells chert, and the Wells chert lies on the Knox dolomite. These are the regions from which we must draw our inferences.

Taking into consideration the succession of strata below the Stones River group in other regions, and their thickness, it is probable that the rocks beneath the surface of this county are approximately as given in the following table, from the top down to the pre-Cambrian floor. These are the rocks which would probably be encountered if a well were drilled on Stones River at the Nashville pike:

| | Feet |
|---|---|
| Ordovician | |
| Stones River | |
| 1. Murfreesboro limestone, unexposed thickness unknown, possibly | 100 |
| 2. Wells chert possibly present, probable thickness | 500 |
| Knox Group (Knox Dolomite of Safford) | |
| 3. Upper Knox (Chepultepec), magnesian and argillaceous | 500 |
| 4. Middle Knox (Copper Ridge), gray dolomite, very cherty | 1,200 |
| 5. Lower Knox, blue to gray dolomite and limestone, very little chert | 600 |
| Cambrian | |
| 6. Conosauga Shale, Knox Shale (Safford) shales and limestones | 1,000 |
| 7. Rome and Knox Sandstone (Safford), calcareous sandstones and shales; may be absent | 800 |

# Generalized Section of the Rocks

Scale: 1 inch=150 feet

| System | Series | | Names of formations | Symbol | Columnar section | Thickness in feet | Area in sq. mi. |
|---|---|---|---|---|---|---|---|
| CARBONIFEROUS | MISSISSIPPIAN | WAVERLYAN | Ft Payne (Tullahoma) | Mt |  | 120 | 2 |
| | | | Unconformity —<br>Chattanooga<br>Unconformity — | Mo | | 15-35 | 3 |
| ORDOVICIAN | CINCINNATIAN | MAYSVILLE | Leipers | Ols | | 0-100 | 1 |
| | | | Unconformity — | | | | |
| | MOHAWKIAN | TRENTON | Cannon | Ocn | | 200-300 | 16 |
| | | | Unconformity —<br>Bigby<br>Unconformity — | Ob | | 0-30 | 1 |
| | | | Hermitage | Oh | | 70-80 | 25 |
| | | | Unconformity — | | | | |
| | | BLACK RIVER | Carters | Oc | | 65-85 | 50 |
| | | | Unconformity — | | | | |
| | CHAZYAN | STONES RIVER | Lebanon | Ol | | 80-120 | 160 |
| | | | Ridley | Or | | 100 | 320 |
| | | | Pierce | Op | | 23-28 | 15 |
| | | | Murfreesboro | Om | | 70+ | 15 |

## in Rutherford County, Tennessee

PLATE III

| Character of topography and soil | General character of formations |
|---|---|
| Tops of highest hill and ridges. Soils sandy, full of chert, poor. | Silicious, blue, fossiliferous limestone, sandy shales and heavy beds of chert; geodes abundant. |
| Steep slopes on brows of highest hills. No soils. | Black, carbonaceous, laminated shale containing pyrite nodules; sandstone of variable thickness at base (Hardin member). |
| Steep slopes near tops of Sumners Knob, Signal Hill and Flag Hill. Soil yellow clay, very shallow. | Knotty earthy limestone and shale, fossils common, especially near the top; **Patystrophia lynx, Rafinesquina alternata, Herbertela sinuata** and many other species of Bryozoa characteristic and abundant. |
| Near tops of highest hills, steep slopes. Soil shallow but very fertile, largely talus, very cherty. | Heavy-bedded, blue or gray, dense or knotty or subcrystalline limestone, seperated by thin beds of calcareous shale; more shaly toward the base; all quite fossiliferous. **Tetradium columnare, Stromatocerium pusulosum, Columnaria alveolata, Actinoceras, tetradium fibratum, Cyrtodonta** and **Cyclonema** abundant and characteristic. |
| Tops of only a few hills. Practically no soil. | Granular, gray or brown, laminated, cross-bedded limestone; fossils usually rare; **Rhynchotrema increbescens** and **Hebertella frankfortensis.** |
| East and South, terraces near tops of hills. Soil yellow, sandy clay, very fertile. West, broad terraces. Soil yellow, sandy, fertile. | East and South sides of county, thin beds of blue, argillaceous limestone and shale in lower third; upper part alternating thin beds blue silicious limestone and shale. Sometimes very fossiliferous. **Tetradium minus** and Bryozoa. Western side, thin-bedded, calcereous, blue sandstone, phosphatic at base, no fossils, weathers brown. |
| Middle or top of most of the hills bordering the county, steep slopes generally without soil. | Heavy bedded, white or dove, granular or dense limestone, sometimes laminated, top few feet ripple-marked; silicified fossils common. **Tetradium cellulosum** and **Columnaria halli** common and characteristic. |
| Hilly regions bordering the central glades. Soil shallow and poor, various shades of red clay. | Thin-bedded, dense, brittle, dove, blue or brown limestone, with shaly partings; beds 1 to 6 inches thick; massive bed of drab limestone 10 or more feet thick near middle; fossils frequently abundant; **Plectambonites sp., Batostoma libana, Leperditia fabulites, Orthis tricenaria, Scenidium anthonense, Escharopora briareus** and **Zygospira saffordi** common and characteristic. |
| Gently rolling surface, larger part of central plain. Reddish-brown clay soil, somewhat cherty, best soil in the county. | Dense, drab, brittle, massive limestone, weathering gray and granular, fluted or platy; sometimes very cherty, oily smell on breaking. **Gonioceras anceps, Stromatocerium rugosum, Camerella volborthi, Protorhyncha ridleyana, Orthis bellarugosa, Rafinesquina minnesotensis, Liospira convexa,** and **Orbignyella sublamellosa** characteristic. |
| Level lands and cliffs among streams. Soil loose, brownish-red, fertile. | Platy layers of dense, blue or drab, brittle limestone, very fossiliferous (Bryozoa), with shaly partings; heavy beds of bluish-brown coarse, crystalline limestone frequently present. |
| Level lands and cliffs along river. Reddish-brown clay soil full of chert. | Dense, drab, brittle, massive limestone, oily smell on breaking, much black chert on weathering, fucoidal markings common; other fossils rare except in chert. **Salterella billingsi, Lophospira perangulata** and **Helicotoma tennesseensis** characteristic. |

## *ROCKS EXPOSED AT THE SURFACE*

The rocks exposed at the surface in Rutherford County all belong to the Ordovician and Mississippian systems, with the exception of hill gravels and alluvium or stream wash. The sequence, names of the subdivisions, and general character of the strata are shown in the columnar section, Plate III. The descriptions of the various strata proceeds in the order of deposition, beginning with the oldest, the Ordovician system.

## ORDOVICIAN SYSTEM

The Ordovician strata which may be seen in Rutherford County are enumerated in the following table, in their natural order:

- Unconformity
- Cincinnatian series
  - Maysville group
    - Leipers formation
- Unconformity
- Mohawkian series
  - Trenton group
    - Cannon limestone
    - Bigby limestone
    - Hermitage formation
- Unconformity
  - Black River group
    - Carters limestone
- Unconformity
- Chazyan series
  - Stones River group
    - Lebanon limestone
    - Ridley limestone
    - Pierce limestone
    - Murfreesboro limestone, base not exposed

### STONES RIVER GROUP

The Stones River group was named by Safford in 1851 and originally included the Carters limestone. The Carters limestone is now considered as the equivalent of the Lowville of Black River age, and the Stones River includes the lower four formations only.

#### Murfreesboro limestone

*Name and definition.*—Safford originally called the Murfreesboro limestone "Central" limestone "for the reason that it is thus presented in the very center of the State" (Geol. Tenn., 1869, p. 259). Safford and Killebrew changed the name to Murfreesboro limestone, because "Murfreesboro is near the center of a circular area of an outcrop of this formation" (Elem. Geol. Tenn., 1900, p. 125). No definite spot was designated as the type locality.

*Areal distribution.*—The Murfreesboro limestone being the lowest formation stratigraphically that is exposed in the county outcrops only where there are local domes and where the upper rocks have been eroded off or cut through by the river. The Murfreesboro limestone does not occupy a circular area from twelve to fifteen miles in diameter, of which Murfreesboro is near the center, as stated by Safford and by Safford and Killebrew, but it does outcrop at several places within this area. Safford confused the Ridley limestone with the Murfreesboro, on account of the great similarity of the two formations and his failure to take into consideration the small domes or wobbles in the strata.

The Murfreesboro limestone occupies a surface area of about fifteen square miles and it does not outcrop anywhere in the Central Basin outside of Rutherford County. It outcrops at several places along the two forks of Stones River, and within the city limits of Murfreesboro. The best exposures are at the following places: along Stones River at the Nashville pike, one mile west of Walter Hill, one mile northeast of the National Cemetery, and at Sand Spring.

*Thickness.*—Since the base of the formation is not exposed anywhere in the county its entire thickness can not be determined. Its maximum exposed thickness is seventy feet at three places, viz., one mile west of Walter Hill, one-half mile up the river from McFaddens Ford, and at Sand Spring.

*Character.*—The Murfreesboro formation consists of heavy beds of dark bluish-gray or drab, dense, brittle limestone. The beds vary from six inches to four feet in thickness and are sometimes separated by thin partings of shale or sand. The stone emits an oily odor upon breaking. The surface layers are sometimes very cherty, especially along streams where solution is rapidly going on. The chert is generally bluish black in color and nonfossiliferous, but after long weathering it is white or rusty red, and fossils can then sometimes be seen in the chert in considerable abundance. Fossils other than fucoids are very rare in the limestone. The fucoids, which are abundant, are about one-quarter of an inch in diameter and consist of granular calcite, which looks like sand and which weathers faster than the more dense body of the rock, giving the rock a worm-eaten appearance.

The presence of chert is wholly a surface phenomenon. The chert is formed from silica taken into solution from the limestone during weathering and redeposited in the form of nodules or plates. Fossils are sometimes the nuclei around which the chert is deposited. Most of the fossils which can be obtained from the Murfreesboro formation are silicified and partially embedded in chert.

The outcrops of Murfreesboro limestone present different appearances, depending largely on the stage in the process of weathering. The following stages may be recognized: (1) When fresh it is dark drab, exceedingly fine-grained and very dense, but contains no chert. Fossils, fucoids and clay seas not recognizable. It is best seen in the quarry one-half mile south of the courthouse. (2) When slightly weathered it is light bluish-gray, with greenish patches and streaks, giving the rounded surfaces a mottled appearance. It is best seen at Stones River on the Nashville pike. (3) When further weathered the surface is full of round holes one-fourth inch in diameter (fucoids), the bedding planes look like clay seams and there are horizontal seams of chert, giving to the rock the appearance of being thin-bedded. It is best seen at the city waterworks. (1) When further weathered the clayey seams have broken down, leaving irregular plates full of blue-black chert. It is best seen where the stream from Fox Camp Spring disappears. This stage looks like the Pierce limestone without the fossils. (5) On further weathering most of the plates are gone and large fragments of chert are strewn about. The chert is black inside and white outside, and sometimes it is full of fossils, mainly gastropods and *Salterella*. (6) The last stage is represented by reddish-brown soil containing small blocks of white chert.

*Section of the Murfreesboro Limestone on Stones River just north of the Nashville pike:*

| | | Feet |
|---|---|---|
| 3. | Light blue or dove-colored, dense, massive, nonfossiliferous limestone, in layers 2 to 4 inches thick, separated by thin, yellowish, sandy-looking partings. Chert and fucoids common. Maximum thickness 40 rods north of bridge | 20 |
| 2. | Grayish-blue, finely laminated, dense, fine-grained limestone, jointed every inch or two; weathers faster than rocks above and below, makes a terrace | ½ to 1½ |

| | |
|---|---|
| 1. Massive, dense, drab, nonfossiliferous limestone, joints 6 to 8 feet apart; chert and fucoids common; thickness at bridge from water level | 20 |

Perhaps the most interesting section of the Murfreesboro formation is on Bradleys Creek at Lascassas. It is as follows:

| | Feet |
|---|---|
| 3. Massive, dense, drab limestone, with blue to fawn-colored chert at the surface | 10 |
| 2. Dense, blue, cherty limestone, containing *Salterella*, *Stromatocerium* and *Orthoceras* | 2 |
| 1. Sandy, laminated, sun-cracked, ripple-marked limestone; chert nodules laminated same as limestone | 15 |

This locality is the only place in the county where the Murfreesboro formation is sandy or laminated and sun-cracked. It shows that the seashore was near Lascassas at that time, or possibly that there had been a slight doming of the strata at this place during the close of the Murfreesboro stage.

*Composition.*—Although the fresh Murfreesboro limestone is dark in color, when it is burned it makes a snow-white quicklime. The dark color is due to bituminous material which is driven off in the process of burning. The chemical analysis is given in Chapter VII.

*Fossils.*—The Murfreesboro limestone is usually unfossiliferous, but sometimes silicified fossils are abundant in the weathered chert. The best localities for collecting fossils are: (1) At the bridge over Stones River on the Nashville pike; (2) in the soil along the street in front of the Central Tennessee Normal School; (3) up the river one-half mile from McFaddens Ford; (4) on Bradleys Creek at Lascassas. The fossils most commonly seen and most characteristic are the following: *Salterella billingsi; Lophospira perangulata; Liospira abrupta; Helicotoma tennesseensis; H. declivis; Leperditia fabulites.*

*Soil.*—The soil derived from the Murfreesboro limestone is a reddish-brown clay of varying shades, frequently containing blue or white chert. It varies in depth from zero along cliffs and glady places to six or eight feet, but probably averages less than four feet in depth.

### Pierce limestone

*Name and definition.*—Safford says, "This group has been so named on account of its fine exposure in the section at Pierce's Mill" (Geol. Tenn., 1869, p. 261). This mill is a half mile south of Walter Hill. The Pierce formation includes the platy, fossiliferous beds and the massive, coarse, granular limestone, between the dense, massive limestones of the Ridley and Murfreesboro formations.

*Thickness.*—The Pierce formation varies in thickness from 23 to 28 feet, but is ordinarily 25 to 27 feet thick.

*Areal distribution.*—The Pierce formation outcrops in irregular rings about the little domes where the Murfreesboro limestone is found. It occupies a total area of about fifteen square miles. There are a good many places where good exposures may be seen, but only a few where the whole thickness is presented for study. The formation is thin, so the outcrops are narrow, averaging less than a quarter of a mile wide. The two largest areas are at Florence, and two miles west of Walter Hill.

*Character.*—The Pierce formation consists of several members, all of them being limestone. The lower or middle part generally consists of massive beds of coarsely crystalline, gray or bluish limestone containing fragments of fossils, mainly ramose Bryozoa. The upper half of the formation is made up of platy layers of dense, blue or gray limestone one-half to two inches thick, intercalated with coarsely crystalline layers covered with fossils. The dense layers are not fossiliferous. The platy beds are separated from each other by films of calcareous shale. The shale weathers rapidly, leaving the thin slabs scattered about.

*Section at the type locality, formerly Pierce's Mill, at Walter Hill:*

| | Feet |
|---|---|
| Ridley | |
| 6. Massive, dense, blue-gray, fossiliferous limestone | 20 |
| Pierce | |
| 5. Thin beds of dense, blue-gray, nonfossiliferous limestone, intermixed with thin beds of gray, coarsely granular, very fossiliferous limestone, separated by shaly partings a fraction of an inch thick | 18 |
| 4. Massive, blue-gray, dense, fine-grained limestone; no fossils except a few brachiopods; very little chert; similar to Murfreesboro limestone | 4 |
| 3. Thin-bedded, dense, gray-blue limestone, unfossiliferous | 2 |
| 2. Massive, drab, unfossiliferous limestone, slightly cherty | 3 |
| Total Pierce | 27 |
| Murfreesboro | |
| 1. Massive, dark, drab, dense limestone, contains some bluish-black chert at top, no fossils | 8 |

Since the Pierce formation varies considerably in character from place to place, several sections will be given to show the variation and the general characters as well.

*Section two miles northwest of Murfreesboro on Stones River:*

| | Feet |
|---|---|
| Ridley | |
| 5. Dense, blue-gray, massive limestone forming glades, and containing *Stromatocerium*, *Orthoceras*, *Gonioceras*, *Rafinesquina* and *Camerella* | 30 |
| Pierce | |
| 4. Light blue, dense, thin-bedded limestone, some layers fossiliferous, separated by films of shale | 11 |
| 3. Light and dark blue, dense and granular, thin beds of fossiliferous limestone | 7½ |
| 2. Gray-blue, irregularly bedded, chunky, nonfossiliferous limestone, much like the Murfreesboro | 8½ |
| Total Pierce | 27 |
| Murfreesboro | |
| 1. Drab, massive, nonfossiliferous limestone | 0 to 20 |

*Section along Lytle Creek in Murfreesboro, back of the jail:*

| | Feet |
|---|---|
| Ridley | |
| 5. Drab, dense, massive limestone | 6 |
| Pierce | |
| 4. Thin beds of gray, shaly, knotty limestone, dark, dense slabs, and blue, granular slabs full of Bryozoa, all ripple- and rill-marked | 6 |
| 3. Light blue, massive, banded limestone, shaly partings, weathers slabby; brachiopods abundant, other fossils rare | 10 |
| 2. Massive, coarse, granular, blue limestone, fragments of brachiopods abundant | 2 |
| 1. Thin-bedded, dove-colored limestone with shaley partings, lower part very fossiliferous, Bryozoa mostly | 10 |
| Total Pierce | 28 |
| Murfreesboro, bed of creek | |

*Section one and one-half miles north of Florence, formerly Wards Mill:*

| | Feet |
|---|---|
| Ridley | |
| 3. Dense, massive, drab limestone, very fossiliferous at top | 40 |
| Pierce | |
| 2. Platy, dense, light-blue, unfossiliferous limestone | 8 |
| 1. Irregular, coarse, granular, cross-bedded layers, some of them full of ramose Bryozoa, and thin, platy, dove-colored layers, some of them covered with flat Bryozoa, and lenticular masses 2 or 3 feet thick, made up of globular Bryozoa (*Diplotrypa*), seen best under the mill, base of Pierce below water in river | 20 |
| Total Pierce | 28 |

*Section at Davis Mill, one mile east of Jefferson:*

| | Feet |
|---|---|
| Ridley | |
| 4. Massive, drab limestone weathering gray, shaly partings, Conioceras and other fossils | 20 |
| Unconformity, wave marked | |
| Pierce | |
| 3. Blue, coarse, crystalline, massive, cross-bedded, suboolitic limestone, weathering brown, few fossils | 4 |
| 2. Massive, blue, coarse, crystalline limestone, weathering brown | 4 |
| 1. Platy, light blue, dense, unfossiliferous beds, and platy, coarse, granular, fossiliferous beds of limestone a few inches thick, rill-marked; exposure varies in thickness up and down stream, base not exposed | 15 |

*Section one and one-fourth miles north of Rucker, at Marshall Knobs:*

| | Feet |
|---|---|
| Ridley | |
| 4. Massive, gray, dense limestone, containing cherty layers, few fossils | 20 |
| Pierce | |
| 3. Gray, coarse, crystalline limestone, ramose Bryozoa and *Columnaria* | 6 |
| 2. Slabby, dense, dove-colored, and granular, gray beds of limestone separated by thin beds of blue shale, fossiliferous | 20 |
| Total Pierce | 26 |
| Murfreesboro | |
| 1. Massive, drab, dense limestone | 4 |

*Section one and three-fourths miles north of Rucker, on road east of River:*

| | Feet |
|---|---|
| Ridley | |
| 7. Massive, dove-colored limestone, no fossils | 10 |
| Pierce | |
| 6. Platy, dense, dove limestone, with gray, granular plates full of Bryozoa | 6 |
| 5. Massive, granular, crystalline, gray limestone, containing ramose Bryozoa | 3 |
| 4. Bluish shale and slabs of limestone | 3 |
| 3. Massive, granular, crystalline limestone, containing ramose Bryozoa (Nicholsonella) | 6 |
| 2. Yellowish, gray and blue, platy limestone, few fossils | 5 |
| Total Pierce | 23 |
| Murfreesboro | |
| 1. Massive, drab, dense limestone, some black chert | 4 |

As shown by these sections the Pierce formation consists of platy, shaly beds with one or more beds of massive, granular limestone, generally in the middle or at the top of the formation, all more or less fossiliferous. It is sometimes very difficult to tell whether an outcrop is Pierce or Lebanon, for they are very similar, although the Lebanon is much thicker. The Murfreesboro and Ridley limestones sometimes contain platy beds very similar to the Pierce.

*Stratigraphic relations.*—The Pierce lies conformably upon the Murfreesboro, to all appearances. Even at Lascassas, where the upper part of the Murfreesboro shows very shallow water conditions, the beds at the contact are parallel, but it is quite probable that there is a slight erosional unconformity at this place, for the upper ten feet of the Murfreesboro is missing one-half mile west of Lofton. The change in the fossils of the two formations is quite marked and may indicate an unconformity of short duration, but the change is more probably due to changed life conditions.

The striking thing about the Pierce formation is its small variation in thickness, 23 to 28 feet, and the marked variation in the position of the granular and the platy beds.

*Fossils.*—The Pierce is rich in fossils, both as to the numbers of species and of specimens. The following species are the most common and characteristic: *Nicholsonella pulchra, Anolotichia explanata, Stictoporella cribrilina, Pianodema stonensis, and Batostoma* sp. The best localities for collecting fossils from the Pierce are: (1) in Murfreesboro on Lytle Creek, back of the jail; (2) at Wards Mill, two miles north of Florence; (3) at Davis Mill near Jefferson; (4) on Bradleys Creek, one mile east of Lascassas; (5) at the mill at Walter Hill.

*Soil.*—The soil derived from the Pierce formation is a soft, reddish-brown clay, frequently containing unweathered slabs, but rarely any chert. It varies in depth from a few inches to six or eight feet. The largest single area of Pierce soil is the Mud Flat, two miles west of Walter Hill.

### Ridley limestone

*Name and definition.*—Safford says, "At Judge Ridley's Mill, near Old Jefferson, there is a good exposure of the rocks of this bed, and hence the name Ridley." (Geol. Tenn., 1869, p. 261.) The mill is now called Davis Mill. Only about thirty feet of the formation is presented in the immediate vicinity of the mill, but the whole formation may be seen on going half a mile south from the mill.

*Areal distribution.*—The Ridley formation is the surface rock of a little over one-half of the county, or about 320 square miles, the level central plain. It is responsible for the greater part of the level land of the county and for the best soil. Outcrops may be seen on practically every square mile of the central plain, but these outcrops expose only a few feet of the whole thickness of the formation.

*Thickness.*—Although there are hundreds of exposures of the Ridley formation in the county, there is no complete section exposing both the bottom and the top in such a position that its thickness could be accurately measured. The complete sections occupy horizontal distances of a half mile or more, and the dip changes so often that the proper correction for dip to be made to the vertical distance between top and bottom is very uncertain.

Safford determined the thickness to be ninety-five feet. His section was measured "at Las Casas, in the northeastern part of Rutherford, not far from the Wilson County line. It was taken on the side of a rocky ridge. The entire *Ridley Bed* is presented in it." (Geol. Tenn., 1860, p. 262.) The exact location of his section cannot be determined from his description. At any rate, he failed to take into account the dip, which is north about 20 feet to the mile in this vicinity. His section was at least half a mile long, which would add 10 feet to the thickness. At most of the places where the Ridley could be measured in its entirety the thickness was about 100 or 105 feet. It gets somewhat thicker as one goes toward the southern side of the county, and reaches a maximum of about 120 feet at Barfield and Marshall Knobs.

*Character.*—The Ridley formation is composed almost wholly of massive, dense, drab-colored limestone, with ordinarily very little chert, but sometimes blue-black or white chert is abundant. The color varies from dove to light brown, and is frequently streaked with lighter colored granular fucoidal markings. The color is largely due to bituminous matter, which can be smelled when the rock is freshly broken, and the color disappears upon heating, leaving a snow-white quicklime. The rock weathers into a light gray and finely granular appearance, but the weathering is very superficial, not more than an inch or two in depth, except where the fucoids dissolve out, leaving the chunk rock at the surface full of holes. There are locally thin-bedded or platy layers closely resembling the Pierce, as at Sulphur Springs, north of Jefferson.

The lithologic similarity between the Murfreesboro and the Ridley formations amounts almost to identity. They are alike in color, hardness, brittleness, presence of chert, bituminous matter, occasional platy layers, the color and form upon weathering, and their influence upon topography and soil. The only discernible difference is in the fossils, which are widely different for the two formations. When fossils are absent, as is frequently the case, the identification is doubtful, unless the Pierce can be demonstrated below or the Lebanon above the formation. The surface is frequently fluted upon weathering and miniature river systems and fantastic shapes are sometimes seen on the surface of large blocks.

The following sections show the general characters and variations of the Ridley formation:

*Section on bank of Stones River, one mile west of Jefferson:*

| Ridley | Feet |
|---|---|
| 6. Top eroded away | |
| 5. Gray, somewhat granular, massive limestone with thin, irregular, shaly partings; some rounded masses of chert; *Stromatocerium*, *Anolotichia*, *Rafinesquina* | 30 |
| 4. Two massive ledges of dense, drab limestone, very resistant to weathering, little chert and no fossils | 13 |
| 3. Thin-bedded, dense, brittle, drab limestone in beds 1 to 2 inches thick, with undulating shaly partings; *Camerella* common | 6 |
| 2. Massive, drab, dense limestone, no fossils | 4 |
| 1. Massive, gray, granular limestone, with two-inch partings of brownish, sub-oolitic limestone, at bed of river, base not exposed | 4 |
| Total Ridley exposed | 57 |

*Section down the east side of Marshall Knob:*

| Ridley | Feet |
|---|---|
| 4. Massive, drab, dense limestone, weathering gray and granular, some chert fossils generally rare, some layers contain *Rafinesquina*, *Herbertella bellarugosa*, Ostracods, small Cephalopods and Gastropods | 80 |
| 3. Thin-bedded, dove-colored limestone, with shaly partings | 10 |
| 2. Drab limestone, like No. 4 | 20 |
| Total Ridley | 110 |
| Pierce | |
| 1. Massive and platy, fossiliferous limestone | 26 |

*Stratigraphic relations.*—The Ridley apparently lies conformable upon the Pierce excepting at Jefferson, where the lowest beds of the Ridley lie upon an undulating surface. Elsewhere the beds below and above the contact are parallel, but there is a marked change in the fauna of the two formations, due probably to changed environment.

The unconformity in any event could not be great, since the Pierce formation is so thin but very constant in thickness, and nowhere shows any evidence of an erosional interval, except the very slight one at Davis Mill.

*Fossils.*—The Ridley contains much fewer fossils than the Pierce and more than the Murfreesboro, but they are not generally a conspicuous feature of the rock. In the northern half of the county *Stromatocerium* is generally present and sometimes abundant, but in the southern half of the county it is absent. The best collecting localities for Ridley fossils are: (1) In front of Vaughn's store at Almaville; (2) in front of the Silver Spring School, two miles north of Florence; (3) at Stones River on the Franklin pike.

The following are the most common and characteristic species, and the presence of any three of them will identify the formation as Ridley: *Stromatocerium rugosum, Camarella volborthi, Hebertella bellarogosa, Goniceras anceps, Orbignyella sublamellosa, Liospira convexa, Rafinesquina minnesotensis,* and *Protorhyncha ridleyana.*

*Soil.*—The soil derived from the Ridley formation is clay of a reddish-brown color, the shade of brown varying somewhat, depending upon conditions after the soil was formed. The subsoil is bright brick-brown, and the surface soil is generally of a darker color on account of the organic matter present. In wet places the soil is bluish yellow, called "crawfish" soil, and where there is a large amount of iron and manganese present these compounds form small, dark-brown concretions, the size of buckshot, and soil containing a large amount of these pellets is called "buckshot" soil. In gentle sways the soil is a mixture of hill wash and residual clay, and is of a yellowish-brown color. The soil covering the Ridley limestone varies in depth from zero on the glades to 5 or 6 feet, but averages less than 3 feet. It is generally without chert, but sometimes chert of a blue, white, or red color is abundant, as in the vicinity of Blackman.

### Lebanon formation

*Name and definition.*—The Lebanon formation was originally named "Glade limestone" by Safford (Geol. Tenn., 1869, p. 258), because it is "pre-eminently the bed of the great *'Cedar Glades'* of the Central Basin." Safford and Killebrew changed the name to Lebanon limestone (Elem. Geol. Tenn., 1910, p. 125), evidently from the town of Lebanon in Wilson County, which is located upon it. The name

Lebanon had previously been used by Safford for the entire Stones River and Carters, but it is now restricted to one formation of the Stones River group.

Safford does not say exactly where the type section of the Lebanon is, and the only section he gives in his original description is "near Readyville." (Geol. Tenn., 1869, p. 263.) This would probably stand as the type section, and is as follows:

"(5) *Carter's Creek limestone.*—The rocks of this bed form the top of the hill, are thick bedded, and have a thickness of 50 feet.

(4) *Glade limestone.*—Thin bedded, flaggy limestone, presenting the usual features of the group; contains a heavy bedded layer, about three feet thick, near the middle, and another near the base. Entire thickness, 118 feet.

(3) *Ridley limestone.*—This constitutes the base of the section, and forms a bluff running down to the level of the water. It has an exposure of 35 feet."

*Areal distribution.*—The Lebanon formation is the surface rock of over one-fourth the area of the county, or about 160 square miles. Its outcrops extend nearly around the county, bordering the flat land of the central plain. The outcrops are from two to five miles wide on the eastern side of the county and from one-half to two miles wide on the western side. It generally is the lowest rock in the hills bordering the county, and the lower part frequently extends out over the flat country in a thin veneer, as it does to a marked extent in the southeastern and the southwestern corners of the country. The outcrop of the lower part of the formation is generally flat or rolling, but the upper part is usually steep, especially where it is still covered with the massive Carters limestone. The whole formation tends to produce flat areas because it weathers so rapidly, and the reason it occupies the hilly districts is on account of the protection from weathering afforded by the resistant Carters limestone above.

*Thickness.*—The Lebanon varies from 80 to 120 feet in thickness, with an average thickness in the county of more than 100 feet. It is generally thinner on the western side of the county and of the maximum thickness on the eastern side. The thinnest section noted was at Bowlings Hill, 4½ miles east of Murfreesboro on the Halls Hill pike. The variation in thickness is probably due to the variation in amount of material originally deposited. It is possible, however, that there was an erosional interval after the Lebanon sediments were laid down and that some of the rock was removed. The evidence favoring an unconformity between the Lebanon and Carters is discussed under the latter heading.

*Character.*—The Lebanon formation is made up very largely of thin layers of dense, drab or dove-colored, fossiliferous limestone, separated by layers a fraction of an inch thick of blue or yellow clay shale. In the lower half of the formation there is frequently a massive bed of drab, dense, unfossiliferous limestone, very similar to the Ridley, varying in thickness from 2 to 11 feet. The platy layers vary from 1 to 6 inches in thickness, averaging 2 or 3 inches, and consist of a great variety of limestone of a gray, dove or drab color. Some layers are dense and unfossiliferous, others coarse, granular and crystalline; some are made up almost wholly of *Plectambonites,* of *Pianodema,* of ramose Bryozoa, of flabellate Bryozoa, of *Leperditia,* or of a combination of fossils; some beds are sandy, some laminated, and some mottled. Ripple-, rill-, and wave-marks are common.

The Lebanon and Pierce formations are very similar in lithological characters, and when a thin, isolated outcrop of platy limestone is found it is often very difficult to tell whether it is Lebanon or Pierce. In such cases the only safe guide is fossils.

Outcrops exposing the whole of the formation may be seen at many places in the county. The following section, taken at Kittrell, is representative of the formation anywhere in the county, although other sections will differ in details.

*Section one-half mile south of Kittrell, from Cripple Creek to top of hill:*

| Hermitage | Feet |
|---|---|
| 10. Blue, laminated, calcareous sandstone, weathering yellow | 15 |
| Carters | |
| 9. Massive, gray or dove limestone, *Tetradium cellulosum* abundant | 80 |
| Lebanon | |
| 8. Granular, gray and dense, dove, unfossiliferous beds, 1 to 3 inches thick, separated by thin films of shale | 40 |
| 7. Gray, compact, laminated, unfossiliferous limestone in beds 6 inches thick | 10 |
| 6. Gray, finely granular, massive limestone, containing lenses up to 4 inches thick of ramose Bryozoa | 2 |
| 5. Granular, gray, and compact, blue, unfossiliferous limestone in beds 1 to 6 inches thick | 16 |
| 4. Knotty, drab limestone in beds one-half inch thick, separated by thin layers of shale, some fossils | 6 |
| 3. Gray, granular slabs of limestone and shale, averaging 2 inches thick, few fossils | 14 |

| | |
|---|---|
| 2. Irregularly bedded, gray, coarse limestone and shale, rill- and ripple-marks, and wave-marks 4 feet long and 6 inches deep, few fossils | 7 |
| Total Lebanon | 95 |
| Ridley | |
| 1. Massive beds 4 feet thick of compact, drab limestone weathering mottled and full of holes (fucoids) | 12 |

*Stratigraphic relations.*—The Lebanon lies conformably on the Ridley, but it is not improbable that parts of the country were out of water at the beginning of the Lebanon sedimentary epoch or during the epoch. There is a considerable change in the fauna between the Ridley and Lebanon formations, but the change is probably due to shallower water conditions of the Lebanon sea and not to an unrecorded interval.

*Fossils.*—The Lebanon is more or less fossiliferous throughout, but fossils are far more abundant in some localities than in others, some beds are barren and others are made up entirely of shells of one species. Beds a foot or two thick composed entirely of a species of *Plectambonites* are sometimes seen, as along the railroad two miles south of Murfreesboro. The best collecting localities for Lebanon fossils are: (1) back of Robinson's store at Big Springs; (2) one-half miles south of Miles Ford; (3) one-fourth mile north of Watson's store on the Shelbyville pike.

The most abundant and characteristic fossils of the Lebanon are: *Plectambonites sp., Scenidium anthonense, Batostoma libana, Escharopora briareus, Leperditia fabulites, Orthis tricenaria, Phragmolites grandis, Pianodema subaequata, Pachydictya cf. foliata, Pterygometopus troosti, Rhynchotrema minnesotensis, Chasmatopora sublaxa, Streptelasma cf. parasiticum, Zygospira saffordi.*

*Soil.*—The soil derived from the Lebanon formation is a reddish brown clay of various shades, depending upon the amount of organic matter present and the state of oxidation of the iron in the clay. It is generally absent or if present so shallow that it can seldom be tilled. What little soil there is present is in the cracks of the rock or mixed up with slabs of rock, but it is sufficient to produce a good crop of cedars. Nearly all of the surface area occupied by this formation is glady. Sometimes the soil is four or five feet deep, and these places will raise good crops during wet seasons, but during a protracted drought the crop dries up and dies, on account of the inability of the broken rock beneath to hold water.

## BLACK RIVER GROUP

This group includes in Rutherford County the Carters limestone of Lowville age, immediately above the Lebanon, and possibly an unnamed formation occurring as a lense above the Carters in the southeastern corner of the county, of Decorah age.

### Carters limestone

*Name and definition.*—The Carters limestone was originally named "Carter's Creek limestone" by Safford (Geol. Tenn., 1869, p. 263), from Carter's Creek in Maury County. Safford and Killebrew (1900) shortened the name to Carter limestone, and Hayes and Ulrich (U. S. G. S. Folio 95, 1903) changed the name to Carters limestone. It was defined to include the massive, dove limestone, 50 to 100 feet thick, above the Lebanon limestone and below the sandy limestone of the "Orthis Bed" or Hermitage.

*Areal distribution.*—The Carters limestone forms the tops of several hills bordering on the central plain, but it forms the middle part of most of the hills bordering the county. The outcrops form irregular bands about the hills, from one-fourth of a mile to a mile wide, over an area of about 50 square miles of the county. Good outcrops may be seen almost anywhere, where it is the surface rock, for it makes steep slopes which are generally devoid of soil. The town of Eagleville and the villages of Milton, Hoover, Short Creek, Donnels, and Versailles are built upon the Carters limestone. A good outcrop may be seen at Bowling Hill, 4½ miles northeast of Murfreesboro.

*Thickness.*—In Rutherford County the Carters varies from 55 to 80 feet in thickness, but it is generally about 65 feet thick. The greatest thickness noted was one-half mile south of Kittrell, and the thinnest one-half mile east of the county line on the Franklin road. In the type area, Maury county, it varies from 40 to 60 feet, and in Wilson county the maximum thickness measured by Safford was 95 feet. As pointed out by Hayes and Ulrich (U. S. G. S., Folio 95), this variation in thickness was not entirely due to variation in amount originally deposited, but was for the most part due to erosion before the deposition of the succeeding formation. The thickness was undoubtedly much more uniform, possibly 80 to 100 feet, at the end of the Carters deposition stage.

*Character.*—The Carters limestone consists of massive beds one to four feet thick of very dense, dove, light blue or gray limestone.

The rock of the lower part is dove or light drab colored, extremely brittle and contains small specks and streaks of colorless calcite, and in general appearance it is exactly like the typical "Birdseye" limestone of New York. In texture and color it resembles lithographic limestone, excepting for the specks and streaks of calcite. The lower part is practically unfossiliferous. The upper part of the formation consists of gray, drab or bluish limestone, which is compact and fine-grained but not of a lithographic texture. It is tough under the hammer and considerably more fossiliferous than the lower part. In some places, especially along the western edge of the county, in the upper part of the formation, there is a four-foot bed of pure white, fine-grained, crystalline limestone which looks much like sugar marble. It shows laminae upon weathering, but when fresh it is a freestone.

*Stratigraphic relations.*—The Carters apparently lies conformably upon the Lebanon, since the strata of the two formations are everywhere parallel. That there is, however, an unconformity (disconformity) between the two formations is shown by the following considerations: (1) the two limestones are lithologically unlike; (2) the fossils are very different; (3) the Lebanon varies in thickness from 80 to 120 feet, the variation being possibly due to erosion prior to the deposition of the Carters; (4) in the Wells Creek basin the Carters lies directly on the Wells chert formation of Canadian age, and the Stones River group is entirely wanting.* This would either indicate that the Stones River had never been deposited at this place, or that it had been deposited and subsequently removed by erosion. (5) In the Appalachian valley of East Tennessee the Blount group, consisting of the Holston, Athens, Tellico and Ottosee formations, in all some 2,000 feet thick, has been determined by Ulrich (loc. cit., opp. p. 608) to be older than the Lowville and younger than the Lebanon. Ulrich, and also Bassler (Bull. 92, U. S. N. M., vol. 2, correlation table), have recently correlated the Carters with the Lowville. The Blount group therefore represents an unrecorded interval between the Lebanon and the Carters of the Central Basin.

*Age and correlation.*—The Carters is now regarded as of Lowville age on the basis of lithologic and faunal similarity, and stratigraphic position above the Stones River (Chazy) and beneath the Trenton.

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*E. O. Ulrich, Revision of the Paleozoic Systems, Bull. Geol. Soc. Am., vol. 22, 1911, p. 671.

The typical Lowville and the Carters are identical in lithologic characters, as noted above, and have a like thickness. The guide fossils, *Tetradium cellulosum* and *Columnaria halli*, are abundant in the Lowville and characteristic of that formation wherever found.

*Fossils.*—*Columnaria halli* is abundant in the Carters and the nearly spherical heads, 2 to 8 inches in diameter, may be seen in nearly all outcrops of the formation. The fossil is silicified as the limestone weathers. This species is not confined to the Carters but occurs rarely in the Pierce and Ridley and in other regions it occurs in the Trenton. *Tetradium cellulosum* is very abundant in the upper part of the Carters and is found in no other formation but the Lowville. Other species occasionally met with are *Tetradium columnare*, *Columnaria carterensis* (similar to *C. halli*), *Streptelasma profundum*, *Dystactospongia minor*, and various species of brachiopods, gastropods and cephalopods recognizable with difficulty.

*Soil.*—The Carters for the most part occurs on steep slopes where very little soil can accumulate, but the upper part is sometimes fairly level, where the less resistant Hermitage limestone has weathered back. The soil is bright, brownish red clay where derived directly from the Carters, but most of the soil overlying this formation is a mixture of residual clay and hill wash from the formations above, and of a yellowish brown color. It is shallow, from zero to three or four feet deep, and contains some chert, silicified fossils and chunks of limestone. The soil is very productive where deep enough to hold water for the crop throughout the summer. Probably less than 10 square miles of the area of the county occupied by Carters outcrops is tilled. The Carters glades grow both cedars and hardwood trees.

## TRENTON GROUP

The Trenton group in Rutherford County consists of at least three formations, the Hermitage at the bottom, Bigby and Cannon.

### Hermitage formation

*Name and definition.*—The Hermitage formation was named by Hayes and Ulrich, who say, "The name 'Hermitage' is derived from the station of that name, situated near the old home of President Jackson, on the Tennessee Central Railroad, where a good section was secured." (U. S. G. S., Folio 95.) Safford first described the formation as "a group of blue, silicious, and sandy limestones, some layers of which are literally made up of individuals of *Orthis tes* *tudinaria,*" and he therefore called the formation "Orthis bed." (Geol. Tenn., 1869, p. 265.)

*Areal distribution.*—In Rutherford County the Hermitage occupies a position at or near the tops of many of the hills in the north and east sides of the county, and outcrops in a strip about one-eighth of a mile wide from 300 to 400 feet below the tops of the high hills and ridges along the county line from Milton, south and west to Fosterville. Along the western side of the county the outcrops are much wider, from one-half to a mile wide, but it occurs only in the hilly districts. The Hermitage is the surface rock of some 25 square miles of the county.

This formation is a conspicuous one in the hills surrounding the Central Basin, and rocks of the same age have been recognized along the Tennessee River in Hardin and Wayne counties, and in the valley of East Tennessee.

*Thickness.*—The Hermitage varies in thickness from 40 to 70 feet in Maury, Williamson, and Davidson counties, and in Rutherford it varies from 50 to as much as 90 feet. This latter thickness probably includes the Bigby formation, which is generally absent in Rutherford County or indistinguishable from the Hermitage. The average thickness of the Hermitage is 70 to 75 feet.

*Character.*—The Hermitage is in general a thin-bedded, blue, silicious limestone, the beds separated by thin layers of blue shale. Along the western side of the county the formation is largely sandstone, calcareous sandstone, and sandy shale, containing laminated phosphatic layers. The formation weathers rapidly into a yellowish or light brown sandy soil, generally containing brown slabs which, when broken, show a blue center.

In the counties along the western border of the Central Basin the Hermitage contains great numbers of *Dalmanella fertilis* Bassler (= *Orthis testudinaria* of Safford), but this shell is rarely seen in the Hermitage of Rutherford County. In this county this formation is not generally fossiliferous, although in some localities fossils occur in considerable numbers.

This formation is of great interest on account of three things: (1) it weathers rapidly into a fertile, sandy soil, and makes a bench around the hills which is generally farmed; (2) it is the only formation in the county which contains lime, sand, and clay in proper proportions to permit of its use as a source of hydraulic cement; (3)

it contains, along the western edge of the county, considerable rock phosphate which will sometime be of commercial value.

The following sections will illustrate the variation in character of the sediments of the Hermitage formation:

*Section one mile northeast of Hoover:*

| Cannon | Feet |
|---|---|
| 5. Massive, drab or gray, compact limestone, some fossils | 40 |
| Hermitage | |
| 4. Irregularly bedded, argillaceous limestone weathering yellow; *Tetradium minus, Rhynchotrema subtrigonale,* and *Halloporina parva* abundant | 22 |
| 3. White, granular, or crystalline, massive limestone containing streaks and spots of yellow calcite; fragments of *Dalmanella fertilis* and other fossils abundant | 8 |
| 2. Thin beds of blue, silicious limestone, laminated sandstone, and fossiliferous limestone, separated by thin beds of greenish-drab, calcareous shale; fossils abundant, especially *Zygospira recurvirostris, Pachydictya cf. foliata* and various ostracods | 50 |
| Total Hermitage | 80 |
| Carters | |
| 1. Massive, dove and gray limestone | 4 |

*Section one-half mile east of Beulah Church, near Williamson County line:*

| Cannon | Feet |
|---|---|
| 6. Massive, gray limestone, thin-bedded and shaly at base | 50 |
| Hermitage | |
| 5. Yellow, sandy, clay shale | 18 |
| 4. Gray, fine-grained, soft, laminated sandstone | 3 |
| 3. Fissile, sandy shale, probably sandstone when fresh | 26 |
| 2. Brown, laminated, phosphatic limestone | 26 |
| Total Hermitage | 73 |
| Carters | |
| 1. Massive, white limestone | 65 |

*Stratigraphic relations.*—The Hermitage lies unconformably upon the Carters, but the strata of the two formations are nearly parallel. The two formations differ greatly in lithologic character and fossil content. The Carters varies from 55 to 80 feet thick in Rutherford County, and from 40 to 95 feet in other localities, the variation being partly due to Paleozoic erosion. In some places the erosional unconformity can be demonstrated. In this region all of the Black River group except the Carters is missing, as well as the lowest Trenton (Curdsville).

*Fossils.*—Fossils cannot be relied upon for the identification of the Hermitage in Rutherford County on account of their scarcity, the sandy character of the rock being more reliable. Fossils are abundant one mile northeast of Hoover and a species of *Monticulipora* is common east of Milton. *Prasopora patera* is common in Maury County, but not a single specimen has been discovered in Rutherford County. Even *Dalmanella fertilis* (*Orthis testudinaria* of Safford) is rarely seen in this county.

*Soil.*—The rocks of the Hermitage weather down rapidly and make a sandy, fertile soil. Along the eastern side of the county the soil contains some clay and undecomposed plates of limestone, but it is very fertile and easily tilled, although the slopes are fairly steep and difficult to approach over the Carters cliff. Along the western side of the county the soil derived from the Hermitage formation is a yellowish sand containing much phosphate. It occurs on a fairly level bench near the top or middle of the hills, is free from chunks of rock except those that have rolled down the hill, is easily tilled and raises good wheat. Corn does not stand wet weather well on this soil, probably on account of the over supply of phosphorus.

### Bigby formation

*Name and definition.*—The Bigby limestone was named by Hayes and Ulrich (U. S. G. S., Folio 95, 1903) from Big Bigby creek in Maury County, Tenn., along which it is well exposed. They defined it as "a nearly uniform series of semi-oolitic or granular, crystalline, laminated, phosphatic limestone, gray or bluish in color, and 30 to 100 feet in thickness." The Bigby includes the Capitol, Dove, and Ward limestones of Safford.

*Areal distribution.*—In Rutherford County the Bigby is nearly always missing, or if present is indistinguishable, from the Hermitage, except in a few localities. It is mapped with the Hermitage, except in a few places along the northwestern line of the county where the two formations could be distinguished on lithologic or faunal grounds. It is safe to say that the Bigby is usually missing in this county, having never been deposited. The only places the Bigby was recognized with certainty were two miles west of Almaville, and near the corner of Williamson, Davidson, and Rutherford counties. It was doubtfully identified 1½ miles northeast of Hoover, and 1½ miles east of Milton. The surface area occupied by Bigby outcrops is between one and two square miles in this county.

*Thickness.*—In thickness the Bigby varies from zero to 30 feet. In Maury County it varies from 30 to 100 feet.

*Character.*—The Bigby varies considerably in character, even among the limited outcrops of this county. West of Almaville it is a gray, massive, granular, laminated limestone, some beds being sandy and others shaly and very fossiliferous, and about 20 feet thick. The fossils occurring abundantly at this locality are *Hebertella frankfortensis, Rhynchotrema increbescens, Hallopora multitabulata var., Platystrophia colbiensis, Tetradium minus,* and other undetermined species. Farther north the formation is a granular, gray or brown, laminated and cross-bedded limestone without fossils. Most of the fossils common in the Bigby of Maury County, especially *Constellaria,* are not present in Rutherford.

*Stratigraphic relations.*—The Bigby lies unconformably upon the Hermitage, although the beds are parallel. The proof of a break in sedimentation is the absence of the Bigby in most of the county, although this may be due to erosion, and the presence of a formation, the Wilmore limestone, in Kentucky between the Hermitage and Bigby. The Bigby is an overlapping formation and probably did not cover the whole of the Nashville dome.

### Cannon limestone

*Name and definition.*—The name Cannon as a formational name was introduced by Ulrich (Bull. Geol. Soc. Am., vol. 22, 1911, p. 417) from Cannon County, Tenn., where the formation is well developed and well exposed. It includes all of the limestones of Trenton age above the Hermitage and below the Chattanooga ("black") Shale, and is in Cannon County fully 300 feet thick.

*Areal distribution.*—The Cannon formation occurs on the steep slopes near the tops of the highest hills and ridges near the county line on the east, south and west sides of the county. Its outcrops occupy a surface area of about 16 square miles in Rutherford County. The bottom of the formation occurs at elevations of 800 to 1,000 feet, depending upon the locality.

*Thickness.*—In thickness the Cannon formation varies between 200 and 300 feet. It is thinnest on the west side of the county and thickest east of Milton. Most of the outcrops in the county have a thickness of about 240 feet.

*Character.*—The Cannon formation consists largely of massive, gray limestones, with occasional thin, shaly streaks. Some of the beds are granular, some knotty and earthy, and many of them very fossiliferous.

The Cannon formation includes undifferentiated Bigby, Flanagan, Perryville, Catheys, and Cynthiana. These formations will no doubt be eventually recognized in central Tennessee, but until the faunas of the different beds of the Cannon are better known it is impracticable to attempt to map the formations as recognized in Kentucky.

*Stratigraphic relations.*—The Cannon lies unconformably upon the Hermitage. The Wilmore limestone is missing in this county, and the Bigby is largely absent. It is not definitely known whether or not there is a break between the Bigby and Cannon, but the absence or thinness of the Bigby indicates either a period of nondeposition or of erosion, hence an unconformity.

*Fossils.*—The most common and easily recognizable fossils in the Cannon are: *Stromatocerium pustulosum, Columnaria alveolata, Lophospira sumnerensis, Actinoceras sp., Tetradium columnare, T. fibratum, Cyrtodonta, and Cyclonema.* Undetermined species of brachiopods, gastropods, pelecypods, corals, bryozoa and other forms are also numerous.

*Soil.*—Since the Cannon limestone always makes steep slopes, the soil is shallow. It is a yellowish, sandy clay and composed of residual clay and hill wash, always containing blocks of chert, geodes, silicified fossils and chunks of limestone which have rolled down from the higher formations. The soil is very fertile and is cultivated in corn wherever possible.

## MAYSVILLE GROUP

### Leipers formation

*Name and definition.*—The Leipers formation was named by Hayes and Ulrich from Leipers Creek in Maury County (U. S. G. S., Folio 95, 1903). They define it, in the eastern half of the Columbia quadrangle, as a "knotty, earthy limestone at the top, with similar but more shaly and highly fossiliferous beds below." It is of Maysville age, or middle Cincinnatian.

*Areal distribution.*—The Leipers occurs in this county on the tops of five hills between Williamson and Rutherford counties, a total area of less than half a square mile. It never was deposited over most of the county, since much of the Nashville dome was above sea level during that time.

*Character.*—The Leipers consists of knotty, earthy limestones and beds of calcareous shale, all more or less fossiliferous, especially at the top. The thickness could not be exactly determined on account of the contact between it and the Cannon being covered, but it is between 90 and 100 feet. The characteristic and abundant fossils are: *Platystrophia ponderosa. Rafinesquina alternata, Hebertella sinuata, Strophomena planoconvexa,* and several species of bryozoa.

*Stratigraphic relations.*—The Leipers lies unconformably upon the Cannon (in Maury County upon the Catheys), which it resembles much in lithologic characters. The Utica and Eden of lower Cincinnatian age are missing in this region but are present in the Cincinnati region. On account of the contact being covered in this region it could not be determined whether it was uneven or not.

### UNCONFORMITY BETWEEN THE CANNON AND THE CHATTANOOGA ("BLACK") SHALE

The upper part of the Ordovician system, the Richmond group, and two whole systems of rocks, the Silurian and Devonian, represented elsewhere by several thousand feet of limestones, sandstones, and shales, are entirely missing in Rutherford County. The center of the Nashville structural dome or arch was an island slightly above sea level during those periods, but the sea surrounded it during several epochs of the Silurian period, and covered one or more sides of the dome at several times in the Devonian period, as shown by the presence of Silurian strata on all sides of the Central Basin, and by Devonian rocks on the north, west, and south sides. The Ordovician strata did not rise far above sea level, for they are not eroded away as they would have been had they been far above sea level. The dome was, however, planed off by the beginning of the Mississippian period, and its flanks covered by wedges of Silurian and Devonian marine deposits, so that the black shale was laid down on a nearly level surface.

# CARBONIFEROUS SYSTEM

## MISSISSIPPIAN SERIES

Of the Mississippian system two formations only are represented in Rutherford County, the Chattanooga formation resting on middle Ordovician, and the Ft. Payne or Tullahoma formation. The Chattanooga formation has been classified by most geologists as Devonian, but is now considered to be basal Mississippian, and it is so classified here.

### Chattanooga formation

*Name and definition.*—The Chattanooga formation was named by C. W. Hayes (Bull. Geol. Sci. Am., II, 1890, p. 142) and included only the black shale below the Ft. Payne chert. It takes its name from the city of Chattanooga, Tenn. The formation was called the "Black Shale Group" by Safford (Geol. Tenn., 1869, p. 331). It consists of three members, the Hardin sandstone, at the base, the "black" shale, and the Maury green shale at the top. (Safford and Killebrew, Elem. Geol. Tenn., 1900, pp. 137-141.)

*Areal distribution.*—The Chattanooga formation may be seen on the brows of the highest hills over which the county line runs on the east, south, and west sides of the county. Its outcrops are always deep and narrow. The formation occupies a surface area of between two and three square miles in the county. The outcrops, although steep, are usually covered with a thin layer of soil or of weathered black shale, and fresh exposures are seldom seen except where it has been excavated for roads. The Hardin sandstone member is generally absent in this county, and the Maury green shale with its phosphatic concretions seems to be entirely missing.

*Thickness.*—The Hardin sandstone member is two inches thick in the hills east of Milton, but at the corner of Cannon, Coffee, and Rutherford counties it forms a lens with a maximum thickness of 25 feet, which filled a small valley on the eroded surface of the Cannon limestone. Elsewhere in the county it is missing or cannot be identified. The "black" shale is present wherever the proper level is presented, and varies from 15 feet on Signal Hill, on the western county line, to 35 feet thick one mile west of the Cannon, Coffee, and Rutherford corner. In general it has a fairly constant thickness of 25 feet.

*Character.*—The Hardin member is a gray, fine-grained sandstone, containing waterworn fragments of Ordovician fossils. No fossils were discovered which belonged to the member itself.

The "black" shale consists throughout of a dead black, laminated, carbonaceous and bituminous shale, containing numerous rounded nodules of iron pyrite or "fools' gold." Conodonts and minute fish teeth occur in abundance, and thin-shelled brachiopods, *Lingula,* are occasionally seen. This member is frequently called "slate,' on account of the property of splitting into thin plates. It is, however, a solidified, carbonaceous mud.

The "black" shale will give a blaze when thrown on a good fire. The bituminous and carbonaceous matter is distilled off as inflammable gases, but the body of the shale will not burn and there is not enough of carbonaceous matter present to support a fire unless other fuel is added. As has been so often pointed out, the "black" shale has no value as fuel, nor does it contain beds of coal. It has been prospected in hundreds of places for coal but none has ever been found. Considerable oil can be distilled from the shale, possibly as much as 10 gallons to the ton, but it cannot be extracted profitably at the present time.

*Stratigraphic relations.*—The Chattanooga lies unconformably on the Cannon on the eastern side of the county, and on the Leipers on the western side. The strata at the contact are usually parallel, but in some places the eroded surfaces of the Cannon is irregular.

### Ft. Payne formation

*Name and definition.*—The Ft. Payne chert was named by C. W. Hayes (Bull. Geol. Soc. Am., vol. II, 1890, p. 142), and was later described by him (U. S. G. S., Folios 2, 4, 6, 8) as a very silicious limestone with heavy beds of chert at the base, above the Chattanooga shale and below the Bangor limestone, and varying in thickness from 75 to 200 feet. The type locality is Ft. Payne, Alabama. Safford called the formation the "Protean member of the Siliceous Group" (Geol. Tenn., 1869, p. 339). Safford and Killebrew renamed the formation Tullahoma, from Tullahoma, Tenn., which is located upon the formation (Elem. Geol. Tenn., 1900, p. 143). Since the terms Ft. Payne and Tullahoma refer to exactly the same formation, the former takes precedence on the ground of priority.

*Areal distribution.*—The Ft. Payne formation occupies the summits of the highest hills and ridges in the county. The largest area is in the southeastern corner of the county line between the Bradyville and Manchester pikes. Only two hills in the western part of the county, Sumners Knob and Signal Hill, are capped with it. The Ft. Payne occupies a surface area of about two square miles of the county.

*Thickness.*—The whole thickness of the Ft. Payne is not shown in Rutherford County. The greatest thickness presented in just east of Praters Hill, where it is 117 feet thick. In Warren County the formation is as much as 225 feet thick (Hayes).

*Character.*—The lower part consists of laminated, sandy shale with several massive beds of yellow chert from a few inches to four feet in thickness. The upper part consists of very silicious, laminated limestones and thin beds of chert. The whole formation gives the appearance of a shaly sandstone, with beds of chert, upon weathering. The limestone, which is blue, coarse, sandy and very fossiliferous, is rarely seen.

The chert results from the decay of beds of limestone and the segregation of the silica in these beds. Geodes, from the size of a marble to the size of a person's head, are abundant throughout the formation. They result from the replacement of the lime in fossils by silica. As the silica crystallizes it expands and makes cracks through the fossil. More silica is deposited in the cracks, especially at the outside, which in crystallizing expands and makes more cracks. In this way the outside grows faster than the inside, which leaves the geodes hollow. Very soon after the formation of the geode the fossil is destroyed, so that it cannot be identified. Under favorable conditions geodes get to be two feet in diameter. Geodes are mainly a surface phenomenon, being formed as the rock decays, but sometimes they are formed in the body of the rock, in which case they are almost always solid.

*Stratigraphic relations.*—The Ft. Payne is unconformable with the Chattanooga, but the beds of the two formations are parallel. Although there is a break in the record at the top of the "black" shale, represented elsewhere by the Maury member, the entire Kinderhookian series and the lower half or three-fourths of the Osagian series, there is very little evidence of erosion in this county. At the north side of the Central Basin the Ridgetop shale, about 100 feet thick, comes between the Chattanooga and Ft. Payne formations. Evidently the top of the Nashville dome was not far above sea level during this last interval.

*Soil.*—The soil derived from the Ft. Payne formation is sandy and full of chert. It works well but is rather poor and raises small crops. It is deficient in lime, phosphorous and organic matter. It is suitable for fruit raising, especially peaches and apples. The principal tree growing in the Ft. Payne soil is the chestnut, which thrives and reaches a large size, up to three or four feet in diameter.

# CHAPTER V.

# GEOLOGIC STRUCTURE

*Definition.*—Geologic structure has reference to the position at the present time of the beds of rock considered as extensive sheets or strata, whether horizontal or inclined or in folds, and also fractures (joints) and displaced strata (faults). Structure has no reference to surface features or topography, but to the attitude of the strata themselves.

When the rocks were deposited as sediment in the bodies of water which covered Rutherford County time after time, they were nearly horizontal. At the present time they are not horizontal, but tipped in various directions. When the strata dip in every direction from a central point, the structure is called a dome or arch. When the rocks are folded upward, the fold is called an anticline, and when the fold is downward like a trough, it is called a syncline. Small domes, anticlines, and synclines are the prevailing structures in Rutherford County.

## NASHVILLE DOME

The whole of Middle Tennessee, from the Cumberland Plateau to the Tennessee River, is in the form of a low dome, known to geologists as the Nashville dome. The center of the dome is on or near the line between Rutherford and Bedford counties in the neighborhood of Fosterville or a few miles west of that place, near Midland. The precise location of the highest point on the dome cannot be determined until a topographic map covering that region is completed.

The top of the "black" shale is taken as a reference surface to show the size and form of the dome. Where the "black" shale has been removed its former position can be calculated by adding the thickness of rock intervening at other places between the surface and the top of the shale. For instance, its former position above Murfreesboro (Court House square) is ascertained to be 1,200 feet above sea level by adding 590 feet, the thickness of rock removed, to the surface elevation, 610 feet, thus:

| | Feet |
|---|---|
| Black shale | 25 |
| Cannon limestone | 240 |
| Hermitage limestone | 70 |
| Carters limestone | 65 |
| Lebanon limestone | 100 |
| Ridley limestone | 90 |
| | 590 |
| Surface elevation | 610 |
| Top of Black Shale | 1,200 |

In like manner the elevation of the "black" shale for other parts of the county was determined, in addition to the places where it is still preserved and its elevation shown upon the topographic map.

The highest elevation occupied by the "black" shale in Middle Tennessee is one mile south of Fosterville, where it is about 1,300 feet above sea level. The shale is still present at this place and more accurate leveling will revise this figure. From the vicinity of Fosterville and Midland the strata dip away in all directions. At Flintville, 40 miles south, the "black" shale has an elevation of about 670 feet, giving a southerly dip of about 15 feet to the mile. The elevation at Centerville, 60 miles west, is 490 feet, a dip of 13 feet to the mile. At Ashland City, 60 miles northwest, the shale is less than 400 feet in elevation, and the dip in this direction is 15 feet to the mile. Between Gallatin and Fountain Head, 55 miles north, the elevation of the shale is about 600 feet, a dip of 15 feet to the mile; at McMinnville, 700 feet (200 feet below the surface), an easterly dip of 17 feet to the mile. The dome is elongated along an axis running northeast and southwest, and the dip is 5 to 10 feet to the mile in these directions. The axis passes through Fosterville and Lascassas and is extended in a line passing through these two towns.

The Central Basin is developed in the top of the dome, but mainly on its northwestern limb. The axis of the dome runs through the middle of the eastern half of the Central Basin and not through the middle or lowest part of the Basin. The Basin has been developed or cut out by the streams on account of the sloping condition of the strata. The several rivers which drain the Basin flow in the general direction of the greatest dip of the strata. The Cumberland River cuts across the northern end of the dome, but this river makes a great bend northward in response to the tendency to slide down the strata.

In Rutherford County the general dip is down stream in the general direction of the branches of Stones River, that is to say, Stones River follows a dip slope. In the extreme northeast corner of the county the top of the Ridley limestone has an elevation of 500 feet; at Pinnacle Knob, 760; at Fosterville, 800; at Donnels Chapel, 720; at Readyville, 630; at Milton, 600; hills north of Lascassas, 700; at Jefferson, 560; and at Murfreesboro, 700. The corresponding elevation of the "black" shale can be determined by adding 500 feet to the above elevations.

## SMALL FOLDS

The Nashville dome is by no means a smooth one, and the dip varies considerably from place to place on account of small folds and domes superimposed on the larger one. In Rutherford County there are numerous undulations in the strata, which are especially noticeable in the middle of the county, as shown on the geologic map. The Murfreesboro and Pierce limestones come to the surface only where the tops of the folds have been cut off by erosion. The maximum height of the folds is about 100 feet.

The Nashville pike crosses Stones River near the center of a small dome about a mile and a half in diameter and 70 or 80 feet high. Down the river from this place to McFaddens Ford there is presented in the cliffs a series of folds, anticlines and synclines, and the river has cut a gorge through them.

Along the east fork of Stones River from Jefferson to Lascassas there are five prominent domes, and several smaller ones. Six of these domes bring the Murfreesboro and Pierce limestones to the surface. At Davis' mill, near Jefferson, the strata are thrown into folds about 100 yards across and 20 feet high. West of Walter Hill there is a dome about three miles in diameter and over 100 feet high. The river cuts across the northwestern flank, exposing 70 feet of Murfreesboro limestone and 27 feet of Pierce. Two miles south of Walter Hill there is a dome two miles in diameter and over 80 feet high, and another at Bettys Ford of about the same dimensions.

Lascassas is at the center of an inverted, boat-shaped fold, a double plunging anticline, three miles long, two miles wide, and 50 feet high. This anticline is on the major axis of the Nashville dome, but is nearly at right angles to it. The Lascassas anticline is of special interest because it is the oldest fold known in the entire Central Basin, having been started in the Murfreesboro epoch. This phase of the fold will be discussed in the next chapter. At the bridge over Stones River, one mile southwest of Lascassas, the dip is southeast 8 feet in 100; one-half mile farther west the dip is west about the same amount.

Murfreesboro stands on the west flank of an anticline six miles long, three miles wide and 70 or 80 feet high. The largest subsidiary dome in the county is in the vicinity of Marshall Knobs. It is about six miles in diameter, and 100 feet high. Other small domes and anticlines occur at Florence, one mile north of Smyrna, at Kings Hill, 2½ miles west of Murfreesboro, at Hoovers, and at many other places.

The most conspicuous syncline or trough in the county extends from Stones River at the Franklin road southeast to Gum, a distance of nine miles. It varies in width from one to three miles, and in depth from 40 to 80 feet. Another syncline extends from Hickory Grove School (one mile east of Sulphur Springs) nearly due south to the U. S. National Cemetery. It is about two miles wide and 100 feet deep at the northern end, and one mile wide and 60 feet deep at its southern end. The two synclines just described are practically continuous with each other. Between the anticlines and on the flanks of the small domes there are also small synclines.

In is interesting to note that nearly all the grist mills in the county are located on the up-stream flanks of the domes. The greatest amount of fall of the river is at these places. The domed structure raises the Pierce limestone so that the eroding power of the water can act on it, and since the Pierce limestone is platy it is much more easily eroded away than the overlying, massive Ridley limestone. The removal of the Pierce limestone leaves the Ridley standing in the form of a cliff, over which the water falls.

## FAULTS

Only two faults have been discovered in the county, both small, one at Davis' mill near Jefferson, and the other two miles south of Christiana. The fault at Davis' mill has a vertical displacement of 20 feet. The fault line runs northwest and southeast and is apparently less than half a mile long and it cannot be followed for any considerable distance on each side of the river on account of being covered with soil. The dip of the fault plane is to the northeast 80 degrees from the horizontal. This fault was made long after the folds were started, but the exact time cannot be determined. The folds were begun at the end of the Pierce sedimentation epoch.

The fault south of Christiana runs northeast and southwest and is less than half a mile long. The maximum displacement is 50 feet and the vertical displacement fades out rapidly in both directions along the fault line. The Lebanon limestone has dropped down south of the fault line, so that the structure is a very small trough cut in two at the north end. The angle of the fault plane could not be definitely determined but it dips at a large angle to the southeast.

## JOINTS

Joints are nearly vertical cracks in the rock, in two sets at nearly right angles to each other. The joints in this county run north 20 degrees east, and east 20 degrees south. They are at varying distances apart, depending upon the kind of rock in which they occur. In the Murfreesboro and Ridley limestones the joints are from 4 to 8 feet apart. In the Pierce and Lebanon limestones the joints are 2 or 3 feet apart, although the distance apart varies considerably and cannot be definitely determined on account of the tendency in these formations to break down into thin slabs. It is probable that the major joints in the fresh rock are at similar distances apart as those in the Murfreesboro and Pierce. The joints in the Carters, Hermitage, and Cannon formations are somewhat closer together than those in the Ridley limestone, or 3 to 4 feet apart. The "black" shale and the Ft. Payne formation are also jointed, and the joints are about the same distance apart as those in the Cannon.

The strata are in beds from a fraction of an inch to a few feet in thickness, and the contact between two beds is called a bedding plane. The beds were laid down in water, and when there was an interruption in deposition a bedding plane was produced. The bedding planes allow water to seep along and emerge as springs or run into wells. Rocks with numerous bedding planes hold more water and also weather more easily than massive rocks, as demonstrated by the Pierce, Lebanon and Hermitage formations. Bedding planes in massive rock determine the position of caves, because solution is relatively rapid along them and along the joints.

# CHAPTER VI.

# GEOLOGIC HISTORY

Geologic history is an account of events in the history of the earth as revealed by the rocks which were laid down in past ages. The rocks, their character, thickness, position with reference to each other, elevation above sea level, and their fossil content, constitute the actual record, and it is the geologist's task to unravel the history of any particular region from the fragmentary record made and preserved by nature herself. Frequently the record of long periods is missing, and then the history must be inferred from the rocks of some other region.

The amount of information to be derived from a study of the rocks is analogous to the information that may be gained about ancient peoples by a study of the ruins left by them, as for example, Indian mounds, ruins of cities like Herculaneum, or the Pyramids of Egypt. Just as human history is divided into periods and epochs, so also is geologic history divided into eras, periods, epochs, and ages.

An account of the events which took place in the formation of the surface features of Rutherford County, since the beginning of the Tertiary period, has been given in Chapter III. The present chapter will deal with the geologic history since the deposition of the oldest rocks up to the present. The subdivisions of geologic time are given on page 30, and the strata deposited in the corresponding times have been discussed in Chapter IV. The rocks were deposited as sediment in a nearly horizontal position in bodies of salt water, bays always connected with the Gulf of Mexico, and sometimes with the Atlantic and Pacific oceans.

Geologic time is not reckoned in years, because the actual length in years in each period is not known. Geologic time is immensely long and to be thought of in terms of millions of years. It is estimated mainly by the number of years it takes now for the deposition in the sea of a foot of sediment, and multiplying that number by the total thickness of the strata. It has been estimated that it takes 1,000 to 1,500 years for a foot of limestone to be deposited. On this basis more than a million years were required for the deposition of the 900 feet of strata to be seen in Rutherford County, and they probably were formed more than 25,000,000 years ago. While these figures are by no means accurate, they will serve to show the immense stretches of time consumed in geologic processes.

## ORDOVICIAN TIME

The oldest rocks exposed in the county were deposited during the early part of Ordovician time, in the Chazyan or Stones River epoch. At that time the seas covered large areas of the North American continent, especially to the east of the Mississippi Valley. The seas abounded with low forms of life, both plants and animals, but there is no indication that there was a living thing on land, either plant or animal, during the Ordovician period.

### Murfreesboro epoch

In the Murfreesboro epoch, that is, the period of time during which the Murfreesboro limestone was deposited, the water of the inland seas was clear and most of the lime was deposited by organisms. The sea was populated with low forms of plants, and algae, whose remains cause the abundant fucoidal markings seen in the limestone. There were also corals, sponges, trilobites, ostracods, molluscs, and brachiopods living in the sea which covered Rutherford County. As the animals and plants died their bodies were covered with soft ooze, and the organic matter was preserved, and now appears as bituminous or oily matter which gives to the Murfreesboro limestone its color and peculiar odor.

The same conditions and relations of land and sea must have persisted throughout the epoch, for the character of the rock is the same through the 70 feet of formation, with one exception. At Lascassas near the close of the epoch, there was an island, or this place was near the seashore, for the deposits are sandy, laminated, ripple-marked and suncracked, and were dry land part of the time, at least between tides. We know that the area which is now Rutherford County was at least 70 miles from land during the Murfreesboro epoch, for in the Wells Creek basin the Stones River formation is wanting.

### Pierce epoch

The Pierce epoch succeeded the Murfreesboro with no discernible lapse of time. The sea bottom was raised, or the water withdrawn, for the water was much shallower than it had been. The water alternated between muddy and clear, causing thin layers of shale and of limestone to be laid down, and massive limestone was formed in some places while shaly limestone was forming in others. The massive beds of granular limestones contain abundant fragments of shells, which would indicate that the water in which they were laid down was in motion, as in strong currents moving in one direction. The numerous rill- and ripple-marks in the platy beds indicate a sea bottom affected by undertow and waves.

The conditions for life were very favorable, for animals, mainly Bryozoa, flourished. The water was probably warm and supplied with food. Between 23 and 28 feet of sediments were deposited during this short epoch. At Davis' mill, near Jefferson, there is a slight unconformity.

### Ridley epoch

At the beginning of the Ridley epoch the land sank abruptly, some of the shallow water animals were killed off, and conditions became again almost exactly as they had been in the Murfreesboro epoch, for the rocks of the two formations are almost identical. The water was probably less than 200 feet deep. The sponge-like animal, *Stromatocerium,* formed colonies on the sea bottom and the cephalopod *Gonioceras* swam about in considerable numbers. Brachiopods were also common inhabitants of the sea of this epoch. Low forms of plants were again present in considerable numbers and their soft bodies were buried in the ooze and appear in the rocks as fucoids. The organic matter buried in the ooze gave rise to oily material present in the rock. No sand was carried to this region by the currents, but the small amount of silica in the limestone is furnished by the silicious sponge spicules present.

### Lebanon epoch

The Lebanon epoch followed the Ridley without any break, and shallow water conditions again returned, much as they had been in the Pierce. Thin beds of limestone and shale were laid down to a depth of 80 to 120 feet. Ripple-, rill- and wave-marks show that the water was shallow during most of the epoch. Sometimes the water cleared and heavy beds of pure limestone were laid down. The sea bottom gradually sank during this epoch, so that nearly the same relations of sea and land and the depth of water were maintained throughout the epoch. At times life was abundant, ostracods shaped like a navy bean lived in great numbers, and bryozoa and brachiopods were also common. A species of brachiopod, *Plectambonites,* lived in enormous numbers at some times and in some places, and their shells make a limestone two feet thick. At other times other species were the dominant ones.

### UNRECORDED INTERVAL

At the close of the Lebanon epoch the region that is now the Central Basin was raised slightly above sea level, and some of the Lebanon deposits were eroded away. In the Appalachian region as much as 2,000 feet of sediments, the Blount group, were laid down in this interval.

### Carters epoch

At the beginning of the Carters or Lowville epoch the region once more sank below the level of the sea. The water was clear, and comparatively deep, some 200 feet, and land was many miles away from this region, as shown by the beds of nearly pure limestone with very little land-derived sediment. The sea was sparsely populated, and corals (*Columnaria* and *Tetradium*) were practically the only animals present, and even plants were rare excepting possibly bacteria and lime-secreting algae. The unfavorable conditions for life were possibly due to a lack of food. These conditions persisted for a short time, and towards the middle of the epoch the sea became more shallow, so that the beds of limestone were interrupted by the deposition of thin films of mud. Toward the close of the epoch the water was so shallow that the sediments were ripple-marked as they were laid down. Beautiful fossil ripple-marks may be seen at the top of the Carters limestone in front of the schoolhouse at Donnels on the Bradyville pike. The Lowville sea was probably our most extensive Paleozoic sea.

### UNRECORDED INTERVAL

At the end of the Carters epoch a large island, about the present dimensions and position of the Nashville dome, was raised slightly above the sea. No great erosion on this island took place, the amount of erosion being indicated by the variation in thickness of the Carters, from 55 to 95 feet. The interval lasted during the remainder of Black River time and the earliest Trenton (Curdsville), while 160 feet of shale (Decorah) and limestone (Plattville) were being deposited in Minnesota and Iowa, the Black River limestone of New York, and the Curdsville of Kentucky. The interval, though geologically short, is to be measured in scores of thousands of years.

### Hermitage epoch

Once more the sea covered this county, but the water was shallow and frequently muddy, for limestones and shales are interbedded. For the first time since the beginning of the Ordovician the sediments were sandy. The sediments were largely sand along the western side of the county, and are progressively more calcareous east and west from that line. The source of the quartz sand is very uncertain. A river coming from some region of granitic rocks, or possibly from some region where the St. Peters sandstone was exposed, evidently emptied into the Hermitage sea near the western border of the county. Whether the source of the sand was the Ozark region, the Wisconsin, or the Appalachian region is undetermined.

The most abundant form of life in the Hermitage sea was a brachiopod, *Dalmanella fertillis,* although it seems to have been rare in Rutherford County. Corals and bryozoa, gastropods and ostracods were also common. The small gastropod *Cyclora* lived in some places in immense numbers, and the shells, which were made of calcium phosphate, are responsible for the beds of phosphate found in the Bigby and Hermitage formations of Middle Tennessee.

It is possible that the phosphatic sandstone of the western side of the county is Bigby. In that event the western half of the county was dry land during the Hermitage epoch, and 75 feet of silicious and shaly limestone was deposited over the eastern half. Then in the Bigby epoch conditions were reversed, the eastern half rose, the western half sank, and 75 feet of shaly and phosphatic sandstone were deposited there. Since the deposits in question are similar, have the same thickness, and occupy the same position with reference to the strata above and below, they are all here considered to be of Hermitage age.

### UNRECORDED INTERVAL

An unrecorded interval of short duration occurred after the deposition of the Hermitage and is represented in Kentucky by the Wilmore limestone. The Nashville dome was again slightly above sea level, some erosion of the Hermitage took place, partly represented by the variation in thickness of that formation, 40 to 70 feet, but the unconformity is not marked.

### Bigby epoch

The sea of the Bigby epoch was very shallow over most of the Nashville dome, and part of Rutherford County was out of water during this time, as indicated by the absence of the Bigby. Sandstones, limestones and shales were deposited, many of the beds are laminated and cross-bedded. Small gastropods whose shells were made of calcium phosphate, lived in enormous numbers in some localities. Brachiopods, bryozoa and corals also inhabited the sea in favorable places.

It is very probable that the Nashville dome was tilted downward toward the north and west during the Bigby epoch, where the sediments were more calcareous and thicker. This would leave an unrecorded interval in that part of the county not covered by the sea. The lost interval is indicated by the absence of the typical upper Bigby fossils in Rutherford County, excepting in two localities.

### Cannon epoch

The Bigby epoch passed directly into the Cannon epoch, and part of the Bigby is included in the Cannon in this county. The Cannon epoch is a complex one and includes several smaller epochs represented by the Flanagan, Perryville, Catheys, and Cynthiana formations in other regions. At the beginning of the Cannon epoch the western side of the Nashville dome was above sea level, while 100 feet or more of limestone was being deposited on the eastern limb. Then the whole dome sank and the Catheys limestone, some 100 feet thick, was laid down. Again the western limb rose, while the eastern sank and another 100 feet of limestones were deposited. These events are recorded by the Catheys limestone in Maury County, zero to 100 feet thick, by the Cannon, 200 feet thick along the western side of Rutherford County and 300 feet of Cannon along the eastern side of the county.

The Cannon sea was clear and abounded in all kinds of invertebrate animals and low forms of plants. Fossils are abundant in the rocks of this age, the most conspicuous ones being corals, pelecypods, gastropods, and brachiopods.

## UNRECORDED INTERVAL

At the end of the Cannon epoch, which was also the end of the Trenton period, the whole of the Nashville dome rose above the sea and remained above for a long time, while some 200 feet of shaly sediments were deposited in the Cincinnati region. The land was not far above sea level, for no great amount of erosion took place during this time.

### Leipers epoch

A small embayment covered the northwestern corner of Rutherford County during this epoch, while about 100 feet of shaly limestone was deposited. Animals similar to those of the Cannon epoch lived in this bay in large numbers.

## UNRECORDED INTERVAL

At the end of the Leipers epoch Rutherford County rose above the sea and remained so for the remainder of the Ordovician period, and the whole of the Silurian and Devonian periods. This lost interval was vastly greater than those noted previously, and to be thought of in terms of millions of years rather than in tens or scores of thousands. Several thousand feet of limestones, sandstones and shales were deposited in other parts of the Mississippi Valley and the Appalachian region during this interval.

At several times during the Silurian period the sea completely surrounded the center of the Nashville dome, and during the Clifton epoch came as close as Maury and Davidson counties. During the Devonian period the sea covered the southern and western limbs of the dome, but Rutherford and parts of the surrounding counties remained as an island during the two periods. The top of the dome was not far, perhaps 100 or 200 feet, above sea level during this long interval and the amount of erosion was not great. Any inequalities of surface were smoothed down so that an almost plane surface resulted by the time the region again sank beneath the sea.

During the long interval represented by the Silurian and Devonian periods great changes were taking place in the forms of life in the sea and on the land. Fishes were evolved in the Ordovician and rose to prominence in Devonian. Amphibians, the first animals to live on dry land, were evolved in the Devonian. The first plants that could live on land also appeared in the Devonian. The record of these events is not preserved in Rutherford County, but is preserved at many other places.

## CARBONIFEROUS TIME

## MISSISSIPPIAN PERIOD

The Mississippian period is represented in this county by deposits formed in the Chattanooga and Ft. Payne epochs. Several later epochs of the Mississippian and Pennsylvanian periods have been represented by several hundred feet of strata, but these have been subsequently removed by erosion.

### Chattanooga epoch

During the early part of the Chattanooga epoch fine quartz sand was supplied to the advancing sea, and the Hardin sandstone was laid down. The sea probably covered only the extreme eastern side of the county in this stage of the Chattanooga epoch, for the Hardin sandstone has been discovered in only two places. On the hills east of Milton the Hardin member is only two inches thick. At the corner of Cannon, Coffee, and Rutherford counties a lense 25 feet thick was deposited in a small valley on the eroded surface of the Cannon limestone. No animals lived on the sandy bottom, at least none have been preserved as fossils.

During the greater part of the Chattanooga epoch the sea covered Rutherford County, and a large part of the Mississippi Valley as well. The waters were stagnant and a very fine, laminated, black mud was deposited, containing iron sulphide and bituminous matter. Few animals could live in this black, stagnant water, and their remains are very scarce, the main ones being small, primitive fishes and low forms of brachiopods. In some localities the water abounded in thin-shelled molluscs and brachiopods, but in this region there were few. The bituminous matter resulted from the decay of plants, both water plants and land plants, and the decay of animal bodies.

## UNRECORDED INTERVAL

In the later part of the Chattanooga epoch, represented in Maury County by the Maury green shale, Rutherford County rose above the water and remained dry land while the Ridgetop shale was being deposited. The height of the land above sea level was not great enough for erosion to produce any marked inequalities in the surface.

### Ft. Payne epoch

During the Ft. Payne epoch the water was rather shallow and the prevailing sediments were silicious and calcareous muds and sand. Animals were very abundant at times, especially crinoids, whose button-like joints make up a considerable proportion of some of the beds. At other times the water was too shallow and too much agitated to be suitable places for animals or even plants to live. The record of the end of this epoch is not preserved in this county, for all the strata younger than the middle of the Ft. Payne which were once present, have been eroded away.

## SUBSEQUENT EVENTS

The geologic history of Rutherford County since the Ft. Payne epoch has left no record in the form of rock strata. The history can only be inferred by the present position of the strata, and the record preserved in adjacent regions.

During the remainder of the Mississippian period and the Pennsylvanian period the Nashville dome was completely under water many times, and several hundred feet of sandstones, shales, limestones, conglomerates, and some coal beds were laid down. These beds were at least 700 or 800 feet thick, for they are still preserved in Short Mountain in Cannon County, and they may have been much thicker.

At some time during the late Pennsylvanian, or possibly the Permian period, the Central Basin area was elevated above sea level, and it never has been below it since. During the Mesozoic era the agents of weathering and erosion were at work removing the rocks previously laid down. Along in the early Cretaceous period the land of Middle Tennessee had been reduced to a featureless plain, varying from sea level at the Tennessee River to possibly 400 or 500 feet above sea level along the eastern side of the Cumberland Plateau. This plain, called the Cretaceous peneplain, is still preserved on the Cumberland Plateau and the top of Short Mountain, but so far as is known there are no remnants of it in the Central Basin or on the Highland Rim. Part of the Cretaceous peneplain is still preserved in Wayne and Lawrence counties.

In the Cretaceous period, at the time of the re-elevation of the Appalachian mountains, eastern and middle Tennessee were re-elevated or tipped toward the west, so that the Cretaceous peneplain was some 1,200 feet above sea level in the region of the Cumberland Plateau and sloped down to sea level toward the west to about the present location of the Tennessee River. Then began another long period of erosion or peneplanation which lasted until the Eocene period of the Cenozoic era. During this period the Highland Rim peneplain was formed, and some of the material resulting from the decay of the Mississippian and Pennsylvanian rocks was carried by rivers westward and deposited in the sea which then covered western Tennessee.

The geologic history since the Eocene period which can be inferred from the present topography of the county and the Central Basin, has already been given in the chapter on Topographic History.

# CHAPTER VII.

# NATURAL RESOURCES

The principal natural resources of Rutherford County, excepting the soil, are limestone, phosphate rock, and mineral water. The county has no deposits of great value which might bring it wealth, such as coal, iron, clay or precious metals. The future prosperity of the people of the county depends, as it has in the past, upon the soil, supplemented with products made from limestone and the development of the deposits of phosphate rock.

## SOIL

The soil is by far the greatest natural asset the county possesses. It ranks with the best soil to be found in the whole State, but at present it is considerably run down and is producing less than one-half of what it can be made to produce. One of the purposes of the geologic survey of the county was to furnish a basis for a study of the soil, and experiments to find ways to increase its productivity and increase the acreage under cultivation are now being carried on. A full report on the soil and its needs will be published by the Agricultural Department of the University of Tennessee.

## BUILDING STONES

Limestones are being used at the present time in the county for masonry, curbing, walks, and other minor uses. The Ridley limestone is admirably adapted for rough masonry, abutments of bridges, substructures of buildings and similar uses. It is massive, has few bedding planes and trims easily into desirable shapes. It is extremely durable against weathering, but it is so hard and brittle that the cost of quarrying and working it into building stone is prohibitive. It has been used to some extent for monuments, and it makes an excellent stone for this purpose. Most of the rock of the central plain is of this kind.

The Carters limestone, along the western side of the county, contains ledges of very white, finely granular limestone which looks like marble and would take a polish. It would make a beautiful building or monumental stone, but the distance from the railroad and a market will preclude its use on any large scale.

Rocks suitable for curbing and of the proper thickness occur commonly in the Lebanon limestone. The thin slabs of this rock have been used for walks and flagging, but the use of stone for curbing, flagging and walks is giving way to cement, which is cheaper and better. The Hermitage sandstone, which occurs in layers a few inches to a foot thick along the western border of the county, is used locally for underpinning, chimneys and monuments, and it is well adapted to these uses. It will stand fire as well as freezing, and it works easily. The Murfreesboro and Ridley limestones are not suitable for chimneys and fireplaces, because they are very dense, and upon heating they crack and spall to pieces. The granular, porous slabs of the Lebanon limestone are suitable for these purposes, because they expand equally and do not break on heating. The sandy limestone of the Hermitage is well adapted for such uses also. None of the limestones will calcine or burn to lime in the moderate heat developed in fireplaces and chimneys, but those rocks should be selected which will not crack upon heating and cooling. This kind of rock is called "fire-rock."

## ROAD MATERIAL

The Ridley and Murfreesboro limestones, which are nearly identical in character, are extensively used in this county for road-making material. The rock quarries and crushes easily, and is therefore cheap. It nevertheless makes a poor macadam road for two reasons; first, it has so little clay in it that it does not bind and make a smooth surface, and second, it is so brittle that it rapidly grinds into dust and is blown away. By the uses of road rollers, a top dressing and a suitable binder, such as asphalt, bitumen or oil, the Ridley and Murfreesboro limestones would make smooth and durable pikes.

The upper part of the Carters limestone is much better adapted for building roads. It is very tough and contains some clay, and would make an excellent water-bound macadam. Its toughness would, however, make it more expensive to crush. It occurs only along the borders of the county, so is less accessible than the other rocks mentioned.

The partially decayed Lebanon limestone is being used in some parts of the county for road material. It is composed of clay and small, broken pieces of rock, and can be shoveled up and placed on the road at little expense. After the new road is used a little while it becomes hard and smooth and stands traffic well. This material is being used especially around Lavergne, and could be used in other parts of the county. It does not occur in thick deposits, but in sheets six inches to a foot thick over the surface of the bed rock in glady places.

Stream gravels have a limited use as road metal along the eastern border of the county. The gravel consists mainly of rounded pieces of chert, which have been washed down from the Ft. Payne formation at the tops of the hills, and broken fragments of limestone and a small amount of clay. After it is packed down the gravel makes a smooth and durable road, even in wet weather. The deposits of stream gravel are very limited in quantity and distribution. The largest deposit occurs two miles east of Big Springs.

## LIME AND CEMENT

No limestone is being burned into quicklime in Rutherford at the present time, because better lime can be shipped and sold for less than it can be produced in this county. Many years ago considerable lime was burned in the county, but the scarcity of fuel has caused the industry to be abandoned. No limestone which contains less than 95 per cent of pure calcium carbonate makes a first-class lime. The analyses of limestones in this county are shown on page 81.

The Hermitage limestone has been used in some places for making hydraulic cement, as mentioned by Safford (Geol. Tenn., 1869, p. 273). Although Rutherford County is provided with an abundance of this rock, it is very improbable that it will ever be of any commercial value for the making of cement, on account of the distance from coal, lack of cheap transportation, and the competition offered by Portland cement, which is of a better quality than any natural hydraulic cement.

## PHOSPHATE

There is in Rutherford County an area of about 15 square miles which contains rock phosphate of probable commercial value. The phosphate occurs on the hills bordering the western side of the county, from Eagleville north to Davidson County. It occurs here in the Hermitage formation, which is largely a sandstone, in laminated layers a few inches to several feet thick. The amount present cannot be determined until a detailed survey is made and numerous prospect holes sunk to determine the thickness. The deposits are all of the "blanket" kind, that is, they occur on fairly level benches. The phosphate is concentrated by the leaching away of the lime which was originally present in these rocks, and the calcium phosphate, which is insoluble in water, is left behind.

Phosphate occurring in sandstone is usually of a low grade, and it is probable that most of the phosphate in this county is of a poor quality. Eventually the low grade phosphate deposits will be valuable, but not until the high grade deposits are exhausted. In order to pay mining at the present time deposits should contain at least 50 per cent of calcium phosphate. The following analyses were from selected samples and are therefore of the highest grade to be expected from this locality.

## WATER RESOURCES

Much of the water which falls as rain runs into the joints and sink-holes, so that there are very few surface streams, outside of the rivers and larger streams, even in wet weather. Nearly every stream in the county excepting Stones River dries up in dry weather, causing an undersupply of water for stock. The reason for this is that the rocks are so impervious that most of the rainwater runs down to the rivers as soon as it falls. The dense nature of the rock, the lack of soil over large areas of the county, and the loss of the forests which once covered the county, are largely responsible for the floods along the lower courses of the branches of Stones River whenever there is an unusually heavy rain. The floods are not usually destructive to property, and successful measures have been taken to control them by the erection of dams and jetties, which impede the flow of the water.

The county is well supplied with ordinary springs, which furnish a considerable amount of drinking water for people and for stock. The water which flows from most of these springs is contaminated in wet weather by surface water which flows into underground channels through sink-holes and joints in the rock. Whenever the water from one of these springs is muddy it is a sure indication that part of the supply is from the surface, and it may be contaminated with typhoid or other disease-making bacteria.

There are several springs in the county which flow sulphur water, the best known one being at Sulphur Spring, one mile north of Jefferson, and another four miles north of Murfreesboro. The "sulphur" in the water is really a gas, hydrogen sulphide. The water is a pure, rock filtered water and no part of it comes directly from the surface. The sulphur gas is derived from the decomposition of iron pyrite with which the water comes in contact. Sulphur water has no particular medicinal value, and the curative properties assigned to it are due to the large quantity which is drunk, and the favorable conditions of rest and pleasant surroundings which accompany the use of the water.

Many wells, especially those where the water comes from the Lebanon limestone, give strong sulphur water. The sulphur is usually in the form of a gas, giving a white sulphur water. Sometimes the water contains the partially decomposed iron sulphide, in which case the water is black, and unfit for drinking or any other domestic use. Black sulphur water contains also sulphuric acid, iron sulphate and other substances which are poisonous to the human system. Fortunately very few wells give this kind of water, and in these cases the water can be made wholesome by filtering through a sand and crushed limestone filter.

The Pierce, Lebanon and Hermitage limestones are the main water-bearing formations in the county. The depth to water varies in different places, depending upon the depth beneath the surface of the water-bearing rocks. In general water is struck anywhere within the central plain at a depth of 60 to 90 feet. The water seeps along the bedding planes and the joints, and it runs from these into the well. The rock is always as full of water as the pore spaces will admit, and dense rock, such as the Murfreesboro, Ridley and Carters limestone, contains very little water. Sometimes water may be obtained by blasting the bottom of a well, which will crack the rock in every direction and allow the water to run in. In a well 100 feet deep from 25 to 50 pounds of dynamite should be used in blasting. Sometimes a well strikes a real underground stream, which are very numerous in this county, and the water in these wells will be muddy in rainy weather and therefore contaminated with surface water.

There is no method by which the depth and quantity of water beneath the surface can be accurately determined, excepting by drilling. The depth beneath the surface of the water-bearing beds of rock can be approximately determined by one acquainted with the geology of a region. In general, the best rule to follow in attempting to find water is to select a convenient location for the well and to drill until water is struck. If the hole is dry it has struck no bedding planes or joints through which water can seep. In this case the best thing to do is to shoot the well with a good charge of dynamite, 25 to 50 pounds, which will shatter the rock for several yards in every direction and allow the water from a considerable distance to flow into the well.

The attempt to locate a supply of ground water by means of a peach tree switch or other "divining rod" is not only useless but foolish. "Water witching" is practiced by many people in this county, and by people in probably every state in the Union, and no water has ever been located by this means, but on the other hand great wrong is done to many people by sincere but misguided "water witches." They cause credulous people to drill one well after another in locations where there is no prospect of striking water on account of the structure and character of the rock.

## COAL, OIL AND GAS

The Black Shale has been prospected time after time for coal, but always with no results except the loss of labor. Black Shale is no indication of coal. Coal results from the accumulation of vegetable matter in marshes. The Black Shale was deposited in a stagnant, salt water sea, and while organic matter is present it is not in the form of coal. Some gas and oil are present in the Black Shale, especially where the Shale is preserved at considerable depths below the surface. In this county the Shale occurs at the tops of the hills and any gas originally present has long since escaped. Some petroleum can be distilled from the shale, but the cost of recovering the oil is more than the oil is worth.

In order for oil and gas to be present in the rocks in paying quantites at least four conditions must be met: (1) there must be a source for the oil, (2) a porous stratum to act as a reservoir, (3) an impervious stratum above the porous one to hold the oil in and keep it from escaping, and (4) the structure of the rock must be such that the oil from a considerable area will flow to the reservoir and be accumulated there.

In Rutherford County the first and fourth of these conditions are present, but the second and third are missing. Oil is derived from organic matter which was buried in the sediments at the time the rocks were deposited. The Murfreesboro and Ridley limestones do contain some oil, and although the quantity is exceedingly small it probably is all that could be produced from the original source. Oil occurs in the tops of domes or anticlines, and this condition is fully met in all of Middle Tennessee. As explained fully in Chapter V, Rutherford County is on the top of the great structural dome called the Nashville dome. In addition to the major dome there are numerous small domes and anticlines all over the county. These places would be admirable places to look for oil, providing all the other conditions were present. The limestone which would have to act as a reservoir is, however, exceedingly dense, almost like glass, and there is no pore space in which the oil can accumulate. Lastly, there is no impervious stratum which might have kept the oil from escaping into the air, although all of the rocks of the lower levels in the county are impervious, but they are fractured and jointed to such an extent that any oil or gas which might have occurred below them could have easily escaped into the air. It is a forlorn hope to expect oil to be discovered in the Central Basin, but still it is not impossible that some will be found. Several deep wells have been drilled in the county, but without results. A little gas has been obtained from one or two of them. The oil and gas conditions in the Central Basin have been discussed by Dr. A. H. Purdue, in the Resources of Tennessee, vol. vi, No. 1.

## MISCELLANEOUS MINERALS

A small quantity of iron pyrite occurs in the Black Shale, and a still smaller quantity occurs in all the other rocks found in the county. When fresh, pyrite has a bright, brassy color, faintly resembling gold, and is called "fools gold." It is of no value unless the deposits consist of thousands of tons. There is no gold or silver ore present in the rocks of this county. Lead sulphide and zinc sulphide have been found in minute quantities in veins in the Ridley and Murfreesboro limestones, as at Lascassas, but it has no value.

Barite, a mineral which is used as a filler in paints and in making lithophone, is found in some localities in the county in amounts up to a few tons. In the southeastern corner of the county the white blocks of barite, or heavy spar, are frequently seen, but the quantity is insufficient to pay mining. The mineral is worth from two to three dollars a ton when loaded on the cars, and since the barite could not be collected and hauled to the railroad for less than four or five dollars a ton, it is obvious that the small deposits in this county are under present conditions of no commercial value.

## LIMESTONE SAMPLES COLLECTED BY ROLF A. SCHOEDER.*

ANALYZED BY DR. J. I. D. HINDS.

| Location | Insoluble | $Fe_2O_3$+ $AI_2O_3$ | $CaCO_3$ | $Ca_3(PO_4)_2$ | $MgCO_3$ |
|---|---|---|---|---|---|
| Cut, one-half mile south of Lavergne, on N., C. & St. L. Ry., 10 ft. sample, Lebanon limestone | 5.16 | .44 | 92.23 | .25 | 1.69 |
| Cut just south Jefferson Pike station, N., C. & St. L. Ry., 7 ft. sample | 3.60 | .60 | 94.20 | .15 | 1.30 |
| North end of cut on N., C. & St. L. Ry. at mile post, Nashville 23, 10 ft sample, Ridley limestone | 3.24 | .30 | 91.35 | .15 | 4.78 |
| South end of cut on N., C. & St. L. Ry. at mile post, Nashville 23, 10 ft. sample, Ridley limestone | 2.16 | .30 | 94.60 | .14 | 2.60 |
| At overhead bridge on N., C. & St. L. Ry. at mile post 23.6, sample 8 ft., Ridley limestone | 3.00 | .28 | 93.93 | .17 | 2.45 |
| Cut on N., C. & St. L. Ry. just south of big iron bridge over Stones River at mile post 30.8 from Nashville, Murfreesboro limestone | 1.54 | .10 | 90.97 | .12 | 7.10 |

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*Samples were obtained by taking a succession of limestone chips from the top to the bottom of the ledge to be analyzed.

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